General Information for the Rules and Regulations for the Classification of Special Service Craft

July 2012

LIFE MATTERS

General Information

1. The 2012 edition of the Rules and Regulations for the Classification of Special Service Craft is a complete reprint of the 2011 edition, consisting of 8 books.

Volume 1, Part 1	Regulations
Rules for the Manufacture, Testing and Certification of Materials	
Volume 3, Part 3	General Requirements and Constructional Arrangement
Volume 3, Part 4	Additional Requirements for Yachts
Volume 3, Part 5	Design and Load Criteria
Volume 4, Part 6	Hull Construction in Steel
Volume 5, Part 7	Hull Construction in Aluminium
Volume 6, Part 8	Hull Construction in Composite
Volume 7, Part 9	General Requirements for Machinery
Volume 7, Part 10	Prime Movers
Volume 7, Part 11	Transmission Systems
Volume 7, Part 12	Propulsion Devices
Volume 7, Part 13	Shaft Vibration and Alignment
Volume 7, Part 14	Steering Systems
Volume 7, Part 15	Piping Systems and Pressure Plant
Volume 7, Part 16	Control and Electrical Engineering
Volume 8, Part 17	Fire Protection, Detection and Extinction

2. A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right-hand digits may be added or omitted depending on the degree of precision required:
   (a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
   (b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
   (c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

   The cross-referencing for Figures and Tables is as follows:
   (a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
   (b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
   (c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

3. The primary changes from the 2011 edition of the Rules are identified in the Guide Book. The effective dates of the indicated changes are 1 January 2012 and 1 July 2012.

4. Until the next edition of the Rules and Regulations for the Classification of Special Service Craft is published, Rule change Notices and/or Corrigenda, as necessary, will be published on the LR Webstore — www.webstore.lr.org – and will be available for downloading free of charge. It is not intended at this time to publish hard copies of future Rule Notices to Existing Rules.

5. In this publication, a shortened version of the Notice has been reproduced listing all the paragraphs that have been altered since the last edition of the Rules. It is followed by a comprehensive Contents list of all books in the set, showing all the titles down to Section level.

Notice – Summary of Changes

Summary of Changes from the 2011 Rules

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1				**Effective Date 1 January 2012**	
3	4	4.3.5	In-water surveys	Paragraph amended	3

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 1				**Effective Date 1 July 2012**	
2	1	1.1.13 to 1.1.15	General	Paragraphs amended	4
2	3	3.5.5	Character of classification and class notations	Paragraph amended	4
2	3	3.6.2	Character of classification and class notations	Paragraph amended	4
2	3	3.8.1	Character of classification and class notations	Paragraph amended	4
2	3	3.8.5	Character of classification and class notations	New paragraph added	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials				**Effective Date 1 July 2012**	
1	4	4.1.1	General requirements for manufacture	Paragraph amended	1
1	5	5.4.2	Non-destructive examinations	Paragraph amended	1
1	5	5.4.3	Non-destructive examinations	New paragraph added	1
1	5	5.5.1	Non-destructive examinations	Paragraph amended	1
1	6	Table 1.6.1	References	Table amended	1
2	1	1.2.3	General requirements for testing	Paragraph amended	1
3	1	1.5.1	General requirements	New paragraph added	1
3	1	1.5.1 to 1.5.2	General requirements	Existing paragraphs renumbered and amended	1
3	1	1.5.4	General requirements	New paragraph added	1
3	1	1.5.3 to 1.5.4	General requirements	Paragraphs deleted	1
3	1	1.5.5	General requirements	Existing paragraph renumbered and amended	1
3	1	1.5.6 to 1.5.7	General requirements	Existing paragraphs renumbered	1
3	1	1.5.8	General requirements	Existing paragraph renumbered and amended	1
3	1	1.5.9	General requirements	Existing paragraph renumbered	1
3	1	1.5.10	General requirements	Paragraph deleted	1
3	1	1.5.11 to 1.5.12	General requirements	New paragraphs added	1
3	1	1.5.11	General requirements	Existing paragraph renumbered and amended	1
3	1	1.5.12	General requirements	Existing paragraph renumbered	1
3	1	1.5.15	General requirements	New paragraph added	1
3	1	1.7.4	General requirements	References amended	1
3	1	Fig. 3.1.1	General requirements	New Figure added	1
3	1	Fig. 3.1.1	General requirements	Existing Figure renumbered	1
3	3	3.1.2	High strength steels for ship and other structural applications	New paragraph added	1
3	3	3.1.2 to 3.1.5	High strength steels for ship and other structural applications	Existing paragraphs renumbered	1
3	3	3.4.1	High strength steels for ship and other structural applications	Paragraph amended	1
3	3	3.4.2	High strength steels for ship and other structural applications	References amended	1
3	3	3.4.4	High strength steels for ship and other structural applications	New paragraph added	1
3	3	3.4.4 to 3.4.7	High strength steels for ship and other structural applications	Existing paragraphs renumbered	1

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Rules for the Manufacture, Testing and Certification of Materials (cont'd)				**Effective Date 1 July 2012**	
3	3	3.5.1	High strength steels for ship and other structural applications	References amended	1
3	3	3.6.1	High strength steels for ship and other structural applications	References amended	1
3	3	3.6.7	High strength steels for ship and other structural applications	New paragraph added	1
3	3	3.6.7 to 3.6.9	High strength steels for ship and other structural applications	Existing paragraphs renumbered	1
3	3	3.6.8	High strength steels for ship and other structural applications	Reference amended	1
3	3	3.8.1	High strength steels for ship and other structural applications	Reference amended	1
3	3	Table 3.3.1	High strength steels for ship and other structural applications	Table amended	1
3	3	Table 3.3.3	High strength steels for ship and other structural applications	New Table added	1
3	3	Tables 3.3.3-3.3.6	High strength steels for ship and other structural applications	Existing Tables renumbered	1
3	3	Table 3.3.3	High strength steels for ship and other structural applications	Existing Table renumbered and amended	1
3	3	Table 3.3.4	High strength steels for ship and other structural applications	Existing Table renumbered and amended	1
3	3	Table 3.3.6	High strength steels for ship and other structural applications	Existing Table renumbered and amended	1
4	2	Table 4.2.2	Castings for ship and other structural applications	Table amended	1
5	1	1.8.7	General requirements	Paragraph amended	1
5	2	2.5.7	Forgings for ship and other structural applications	Paragraph amended	1
5	3	3.5.1	Forgings for shafting and machinery	Paragraph amended	1
5	3	3.5.4	Forgings for shafting and machinery	Paragraph amended	1
5	3	Table 5.3.4	Forgings for shafting and machinery	Table amended	1
8	1	1.1.3	Plates, bars and sections	Paragraph amended	1
8	1	1.1.5	Plates, bars and sections	New paragraph added	1
8	1	1.1.5 to 1.1.6	Plates, bars and sections	Existing paragraphs renumbered	1
8	1	1.8.3	Plates, bars and sections	Paragraph amended	1
8	1	Table 8.1.3	Plates, bars and sections	Table amended	1
8	1	Table 8.1.4	Plates, bars and sections	Table amended	1
10	4	4.6.8	Studless mooring chain cables	Reference amended	1
11	1	1.8.1	General	Paragraph amended	1
11	1	Table 11.1.1	General	Table amended	1
11	3	3.1.6 to 3.1.7	Electrodes for manual and gravity welding	Paragraphs amended	1
11	3	3.2.2	Electrodes for manual and gravity welding	New paragraph added	1
11	3	3.2.2 to 3.2.5	Electrodes for manual and gravity welding	Existing paragraphs renumbered	1
11	3	3.3.2	Electrodes for manual and gravity welding	New paragraph added	1
11	3	3.3.2 to 3.3.12	Electrodes for manual and gravity welding	Existing paragraphs renumbered	1
11	3	3.3.4	Electrodes for manual and gravity welding	Paragraph amended	1
11	3	3.5.2	Electrodes for manual and gravity welding	New paragraph added	1
11	3	3.5.2 to 3.5.5	Electrodes for manual and gravity welding	Existing paragraphs renumbered	1
11	3	3.5.3	Electrodes for manual and gravity welding	Reference amended	1
11	3	3.7.3	Electrodes for manual and gravity welding	Reference amended	1

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2012**
11	3	Table 11.3.1	Electrodes for manual and gravity welding	Table deleted	1
11	3	Table 11.3.1	Electrodes for manual and gravity welding	New Table added	1
11	3	Table 11.3.2	Electrodes for manual and gravity welding	Table amended	1
11	3	Table 11.3.3	Electrodes for manual and gravity welding	Table amended	1
11	4	4.1.8 to 4.1.9	Wire-flux combinations for submerged-arc automatic welding	Paragraphs amended	1
11	4	4.3.2	Wire-flux combinations for submerged-arc automatic welding	New paragraph added	1
11	4	4.3.2 to 4.3.8	Wire-flux combinations for submerged-arc automatic welding	Existing paragraphs renumbered	1
11	4	4.4.2	Wire-flux combinations for submerged-arc automatic welding	Paragraph amended	1
11	4	4.7.1	Wire-flux combinations for submerged-arc automatic welding	Paragraph amended	1
11	4	Table 11.4.1	Wire-flux combinations for submerged-arc automatic welding	Table deleted	1
11	4	Table 11.4.1	Wire-flux combinations for submerged-arc automatic welding	New table added	1
11	4	Table 11.4.2	Wire-flux combinations for submerged-arc automatic welding	Table amended	1
11	4	Table 11.4.3	Wire-flux combinations for submerged-arc automatic welding	Table amended	1
11	5	5.1.14 to 5.1.15	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Paragraphs amended	1
11	5	5.2.3	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	New paragraph added	1
11	5	5.2.3 to 5.2.11	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Existing paragraphs renumbered	1
11	5	5.2.7	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Reference amended	1
11	5	5.3.2	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Reference amended	1
11	5	5.3.3	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	New paragraph added	1
11	5	5.3.3 to 5.3.6	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Existing paragraph renumbered	1
11	5	Table 11.5.1	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	Table deleted	1
11	5	Table 11.5.1	Wires and wire-gas combinations for manual, semi-automatic and automatic welding	New Table added	1
11	7	7.1.9 to 7.1.10	Consumables for use in one-side welding with temporary backing materials	Paragraphs amended	1
11	7	7.2.2	Consumables for use in one-side welding with temporary backing materials	New paragraph added	1

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Rules for the Manufacture, Testing and Certification of Materials (cont'd)				**Effective Date 1 July 2012**	
11	7	7.2.2 to 7.2.7	Consumables for use in one-side welding with temporary backing materials	Existing paragraphs renumbered	1
11	7	7.2.4	Consumables for use in one-side welding with temporary backing materials	Reference amended	1
11	7	7.3.2	Consumables for use in one-side welding with temporary backing materials	New paragraph added	1
11	7	7.3.2	Consumables for use in one-side welding with temporary backing materials	Existing paragraph renumbered	1
11	7	7.3.3	Consumables for use in one-side welding with temporary backing materials	Existing paragraph renumbered and amended	1
11	7	7.3.4	Consumables for use in one-side welding with temporary backing materials	Reference amended	1
11	7	7.3.4 to 7.3.7	Consumables for use in one-side welding with temporary backing materials	Existing paragraphs renumbered	1
11	7	Table 11.7.1	Consumables for use in one-side welding with temporary backing materials	Table deleted	1
11	7	Table 11.7.1	Consumables for use in one-side welding with temporary backing materials	New table added	1
11	9	9.5.3	Consumables for welding aluminium alloys	Reference amended	1
12	2	2.12.4	Welding Procedure Qualification Tests for Steels	Paragraph amended	1
12	2	2.15.7	Welding Procedure Qualification Tests for Steels	Reference amended	1
12	2	2.15.8	Welding Procedure Qualification Tests for Steels	Paragraph amended	1
12	2	2.15.9	Welding Procedure Qualification Tests for Steels	References amended	1
12	2	Table 12.2.2	Welding Procedure Qualification Tests for Steels	Table amended	1
12	2	Table 12.2.3	Welding Procedure Qualification Tests for Steels	New Table added	1
12	2	Tables 12.2.3-5	Welding Procedure Qualification Tests for Steels	Existing Tables renumbered	1
12	2	Table 12.4.10	Welding Procedure Qualification Tests for Steels	Table amended	1
13	2	2.2.2	Specific requirements for ship hull structure and machinery	Paragraph amended	1
13	2	2.12.6	Specific requirements for ship hull structure and machinery	Paragraph amended	1
13	4	4.15.1	Specific requirements for fusion welded pressure vessels	Paragraph amended	1
13	8	8.3.2	Specific requirements for welded aluminium	New paragraph added	
13	8	8.3.2 to 8.3.3	Specific requirements for welded aluminium	Existing paragraphs renumbered	
13	8	8.4.1	Specific requirements for welded aluminium	References amended	
13	8	Table 13.8.1	Specific requirements for welded aluminium	New Table added	
13	8	Tables 13.8.1-2	Specific requirements for welded aluminium	Existing Tables renumbered	

Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials (cont'd)					**Effective Date 1 July 2012**
14	2	2.6.4	Tests on polymers, resins, reinforcement and associated materials	Paragraph amended	1
14	2	2.11.2	Tests on polymers, resins, reinforcement and associated materials	Paragraph amended	1
14	3	Table 14.3.5	Testing procedures	Table amended	1
14	5	5.14 to 5.14.1	Control of material quality for composite construction	New sub-Section added	1
14	5	5.14	Control of material quality for composite construction	Existing sub-Section renumbered	1
14	5	Table 14.5.8	Control of material quality for composite construction	New Table added	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 3					**Effective Date 1 January 2012**
1	7	Table 1.7.1	Inspection, workmanship and testing procedures	Table amended	1
5	6	6.8.3	Anchor cable	Paragraph deleted	1
5	6	6.8.3 to 6.8.5	Anchor cable	New paragraphs added	1
5	9	9.4.1	Structural details	Paragraph amended	1
5	9	9.4.2	Structural details	Paragraph deleted	1

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 3					**Effective Date 1 July 2012**
2	6	6.6.4	Machinery space arrangements	Paragraph amended	4
2	8	8.5.1	Particular requirements for multi-hulls	Paragraph amended	4
2	9	9 to 9.5.1	Navigation in ice	New Section added	4
3	1	1.3.1	General	Paragraph amended	4
3	2	2.17.3 to 2.17.5	Rudders	Paragraphs deleted	4
3	2	2.17.2 to 2.17.3	Rudders	New paragraphs added	4
3	2	2.18.2	Rudders	Paragraph amended	4
3	2	2.19.8	Rudders	New paragraph added	4
4	7	7.5.3 to 7.5.4	Portlights, windows and viewing ports, skylights and glass walls	Paragraphs amended	4
4	7	7.9.1	Portlights, windows and viewing ports, skylights and glass walls	Paragraph amended	4
4	7	7.12.5	Portlights, windows and viewing ports, skylights and glass walls	Paragraph amended	4
4	7	7.16 to 7.16.8	Portlights, windows and viewing ports, skylights and glass walls	New sub-Section added	4
4	7	Fig. 4.7.2	Portlights, windows and viewing ports, skylights and glass walls	New Figure added	4
4	11	11.4.2	Ventilators	New paragraph added	4
4	11	11.4.2 to 11.4.7	Ventilators	Existing paragraphs renumbered	4
5	3	3.3.1	Service group factors	Paragraph amended	4
5	6	6.4.1	Anchor cable	Paragraph amended	4

Notice – Summary of Changes

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 4					**Effective Date 1 July 2012**
2	8	8.1.1 to 8.1.2	Navigation in first-year ice conditions	Paragraphs deleted	4
2	8	8.1.1	Navigation in first-year ice conditions	New paragraph added	4
2	8	8.1.3	Navigation in first-year ice conditions	Existing paragraph renumbered	4
2	9	9 to 9.1.2	Support yacht craft	New Section added	4
3	1	1.2.1	Hull design and construction parameters	Paragraph amended	4
3	5	5.1.3	Deck fittings	Paragraph amended	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 5					**Effective Date 1 July 2012**
2	2	Table 2.2.1	Definitions and symbols	Table amended	4
3	2	Table 3.2.2	Nomenclature and design factors	Table amended	4
4	2	Table 4.2.1	Nomenclature and design factors	Table amended	4
5	2	2.2.1	Hull girder load criteria for mono-hull craft	Paragraph amended	4
5	3	3.2.1	Hull girder load criteria for multi-hull craft	Paragraph amended	4
5	4	4.2.1 to 4.2.3	Primary load criteria for multi-hull craft	Paragraphs amended	4
5	4	4.3.1	Primary load criteria for multi-hull craft	Paragraph amended	4
5	4	4.3.4 to 4.3.5	Primary load criteria for multi-hull craft	Paragraphs amended	4

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Part 6					**Effective Date 1 July 2012**
4	7	7.2.1	Bulkheads and deep tanks	Paragraph amended	4
5	3	Table 5.3.1	Vehicle decks	Table amended	4
5	6	6.3.1	Helicopter landing areas	Paragraph amended	4
5	6	6.3.2	Helicopter landing areas	Paragraph deleted	4
5	6	6.4	Helicopter landing areas	Sub-Section retitled	4
5	6	6.4.1	Helicopter landing areas	Paragraph amended	4
5	6	Table 5.6.2	Helicopter landing areas	Table amended	4
5	7	7.1.1	Strengthening requirements for navigation in ice conditions	New paragraph added	4
5	7	7.1.1 to 7.3.1	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	7	7.4.1	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	7	7.4.2	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.4.3 to 7.4.4	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.5 to 7.9.6	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 7					**Effective Date 1 July 2012**
2	2	2.4.1	Materials	Paragraph amended	4
2	2	Table 2.2.1	Materials	Table deleted	4
4	7	7.2.1	Bulkheads and deep tanks	Paragraph amended	4
5	6	6.3.1	Helicopter landing areas	Paragraph amended	4
5	6	6.4	Helicopter landing areas	Sub-Section retitled	4
5	6	6.4.1	Helicopter landing areas	Paragraph amended	4
5	6	Table 5.6.2	Helicopter landing areas	Table amended	4
5	7	7.1.1	Strengthening requirements for navigation in ice conditions	New paragraph added	4
5	7	7.1.1 to 7.3.1	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	7	7.4.1	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered and amended	4
5	7	7.4.2	Strengthening requirements for navigation in ice conditions	Existing paragarph renumbered	4
5	7	7.4.3 to 7.4.4	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.4.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.5	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	7	7.5.1 to 7.5.4	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	7	7.5.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	7	7.5.6 to 7.9.6	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4

Ch	Section	Para	Section Title	Status	Notice
Part 8					**Effective Date 1 July 2012**
2	1	1.4.1	General requirements	New paragraph added	4
2	1	1.4.1 to 1.4.3	General requirements	Existing paragraphs renumbered	4
2	2	2.16.1	Materials	Paragraph amended	4
2	3	3.3.4	General construction process	Paragraph amended	4
2	3	3.9.14 to 3.9.15	General construction process	Paragraphs deleted	4
2	3	3.9.16 to 3.9.19	General construction process	Existing paragraphs renumbered	4
2	4	4.5 to 4.5.2	Additional procedures for sandwich construction	Sub-Section deleted	4
2	5	5.7.2	Details and fastenings	Paragraph amended	4
2	5	5.9	Details and fastenings	Sub-Section retitled	4
2	5	5.12.1	Details and fastenings	Paragraph amended	4
2	5	5.12.2	Details and fastenings	Paragraph deleted	4
2	5	5.12.2	Details and fastenings	New paragraph added	4
3	1	1.2.3	General	Paragraph amended	4
3	1	1.2.4	General	New paragraph added	4
3	1	1.2.4	General	Existing paragraph renumbered	4
3	1	1.2.6	General	Paragraph deleted	4
3	1	1.5.1	General	Paragraph amended	4
3	1	1.13.11 to 1.13.13	General	Paragraphs deleted	4
3	1	1.13.14 to 1.13.16	General	Existnig paragraphs renumbered	4
3	1	1.20.2	General	Paragraph amended	4
3	1	Fig. 3.1.3	General	Figure deleted	4
3	1	Table 3.1.1	General	Table retitled and amended	4
3	1	Table 3.1.2	General	Table retitled and amended	4
3	1	Tables 3.1.3-7	General	New Tables added	4
3	1	Tables 3.1.3-5	General	Existing Tables renumbered	4

Notice – Summary of Changes

Ch	Section	Para	Section Title	Status	Notice
Part 8 (cont'd)				**Effective Date 1 July 2012**	
3	1	Table 3.1.11-12	General	New Tables added	4
3	2	2.3.1	Minimum thickness requirements	Paragraph amended	4
3	2	2.4	Minimum thickness requirements	Sub-Section retitled	4
3	2	2.4.1 to 2.4.2	Minimum thickness requirements	Paragraphs amended	4
3	2	2.5 to 2.5.5	Minimum thickness requirements	New sub-Section added	4
3	2	2.5	Minimum thickness requirements	Existing sub-Section renumbered	4
3	2	2.5.2	Minimum thickness requirements	Existing paragraph renumbered and amended	4
3	2	2.6 to 2.6.4	Minimum thickness requirements	Sub-Section deleted	4
3	2	2.9.1	Minimum thickness requirements	Paragraph amended	4
3	2	Fig. 3.2.1	Minimum thickness requirements	Figure deleted	4
3	2	Table 3.2.2	Minimum thickness requirements	New Table added	4
3	3	3.4.5	Shell envelope laminate	Paragraph amended	4
3	3	3.5.5	Shell envelope laminate	Paragraph amended	4
3	3	3.6.1	Shell envelope laminate	Paragraph amended	4
3	3	3.14.1 to 3.14.2	Shell envelope laminate	Paragraphs amended	4
3	3	3.14.3	Shell envelope laminate	New paragraph added	4
3	3	3.15.1	Shell envelope laminate	Paragraph amended	4
3	3	Fig. 3.3.3	Shell envelope laminate	New Figure added	4
3	3	Fig. 3.3.3	Shell envelope laminate	Existing Figure renumbered	4
3	4	4.19.5	Shell evelopev framing	Paragraph amended	4
3	5	5.22.	Single bottom structure and appendages	Paragraph amended	4
3	6	6.6.4	Double bottom structure	Paragraph amended	4
3	6	6.9.6	Double bottom structure	Paragraph amended	4
3	7	7.3.6	Bulkheads and deep tanks	Paragraph amended	4
3	7	7.4.6	Bulkheads and deep tanks	Paragraph amended	4
3	7	7.16.5	Bulkheads and deep tanks	Paragraph amended	4
3	8	8.3.5	Deck structures	Paragraph amended	4
3	8	8.4.5	Deck structures	Paragraph amended	4
3	8	8.6.5	Deck structures	Paragraph amended	4
3	8	8.12.6	Deck structures	Paragraph amended	4
3	8	8.12.8	Deck structures	Paragraph amended	4
3	8	Fig. 3.8.2	Deck structures	Figure retitled	4
3	9	9.1.8	Superstructures, deckhouses and bulwarks	New paragraph added	4
3	9	9.3.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.4.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.5.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.6.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.7.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.8.5	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.25.6	Superstructures, deckhouses and bulwarks	Paragraph amended	4
3	9	9.25.14	Superstructures, deckhouses and bulwarks	Paragraph amended	4
4	2	2.1.1	Minimum thickness requirements	Paragraph amended	4
4	2	2.1.2	Minimum thickness requirements	New paragraph added	4
4	2	2.1.2	Minimum thickness requirements	Existing paragraph renumbered	4
4	2	Table 4.2.1	Minimum thickness requirements	New Table added	4
4	3	3.3.6	Shell envelope laminate	Paragraph amended	4
4	3	3.5.7	Shell envelope laminate	Paragraph amended	4
4	3	3.7.6	Shell envelope laminate	Paragraph amended	4
4	5	5.3.2	Single bottom structure and appendages	Paragraph amended	4
4	6	6.5.4	Double bottom structure	Paragraph amended	4

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Ch	Section	Para	Section Title	Status	Notice
Part 8 (cont'd)				**Effective Date 1 July 2012**	
4	8	8.4.5	Deck structures	Paragraph amended	4
5	2	2.9.4	Special features	Paragraph amended	4
5	3	3.1.5	Vehicle decks	Paragraph amended	4
5	6	6.1.1	Strengthening requirements for navigation in ice conditions	New paragraph added	4
5	6	6.1.1 to 6.3.1	Strengthening requirements for navigation in ice conditions	Paragraphs deleted	4
5	6	6.4 to 6.4.3	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	6	6.4.3	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered and amended	4
5	6	6.4.4	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	6	6.5	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	6	6.5.1	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	6	6.5.2 to 6.5.3	Strengthening requirements for navigation in ice conditions	Existing paragraphs renumbered	4
5	6	6.5.4	Strengthening requirements for navigation in ice conditions	Paragraph deleted	4
5	6	6.5.5	Strengthening requirements for navigation in ice conditions	Existing paragraph renumbered	4
5	6	6.6 to 6.6.2	Strengthening requirements for navigation in ice conditions	Existing sub-Section renumbered	4
5	6	6.7 to 6.9.6	Strengthening requirements for navigation in ice conditions	Sub-Sections deleted	4

Ch	Section	Para	Section Title	Status	Notice
Part 9				**Effective Date 1 July 2012**	
1	1	1.1.1	General requirements	Paragraph amended	5

Ch	Section	Para	Section Title	Status	Notice
Part 10				**Effective Date 1 July 2012**	
1	8	8.6.5	Piping systems	New paragraph added	5
1	13	13.3.2	Electronically controlled engines	Reference amended	5
1	13	13.6.1	Electronically controlled engines	Reference amended	5
1	14	14.2.6	Programme for trials of diesel engines to assess operational capability	Reference amended	5

Ch	Section	Para	Section Title	Status	Notice
Part 13				**Effective Date 1 July 2012**	
4	1	1.2.1	Shaft alignment	Paragraph amended	5

Ch	Section	Para	Section Title	Status	Notice
Part 15				**Effective Date 1 July 2012**	
1	8	8.2.4	Plastics	Reference amended	5
1	8	8.6.6	Plastics	Reference amended	5
1	9	9.1.2 to 9.1.3	Austenitic stainless steel	Paragraphs amended	2, 5

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Ch	Section	Para	Section Title	Status	Notice
Part 16					**Effective Date 1 January 2012**
1	1	1.1.3	General requirements	Reference amended	5
1	1	1.1.4	General requirements	Reference amended	5
1	1	1.2.3	General requirements	Reference amended	5
1	1	1.2.4	General requirements	Paragraph amended	5
1	1	1.2.7	General requirements	Paragraph amended	5
1	1	1.2.9	General requirements	Paragraph deleted	5
1	1	1.2.10	General requirements	Existing paragraph renumbered and reference amended	5
1	2	2.1.1	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.2.1	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.2.3	Essential features for control, alarm and safety systems	New paragraph added	5
1	2	2.2.3 to 2.2.7	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.3.1	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.3.3	Essential features for control, alarm and safety systems	Paragraph deleted	5
1	2	2.3.3 to 2.3.5	Essential features for control, alarm and safety systems	New paragraphs added	5
1	2	2.3.4	Essential features for control, alarm and safety systems	Existing paragraph renumbered	5
1	2	2.3.5	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.3.6	Essential features for control, alarm and safety systems	Existing paragraph renumbered	5
1	2	2.3.7 to 2.3.8	Essential features for control, alarm and safety systems	Existing paragraphs renumbered and amended	5
1	2	2.3.9 to 2.3.14	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.3.13	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.3.15	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.3.16 to 2.3.17	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.3.18	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.5.8	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.5.11	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.8.4	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.8.6	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.8.7	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.9.3	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.9.5	Essential features for control, alarm and safety systems	Paragraph amended	5
1	2	2.10.7	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.10.12	Essential features for control, alarm and safety systems	References amended	5
1	2	2.10.16 to 2.10.19	Essential features for control, alarm and safety systems	Paragraphs deleted	5

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Ch	Section	Para	Section Title	Status	Notice
Part 16 (cont'd)				**Effective Date 1 January 2012**	
1	2	2.10.20	Essential features for control, alarm and safety systems	Existing paragraph renumbered and amended	5
1	2	2.10.21	Essential features for control, alarm and safety systems	Paragraph deleted	5
1	2	2.10.22 to 2.10.25	Essential features for control, alarm and safety systems	Existing paragraphs renumbered	5
1	2	2.11.6	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.11.9	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.13.1	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.13.7	Essential features for control, alarm and safety systems	Reference amended	5
1	2	2.14.1	Essential features for control, alarm and safety systems	Reference amended	5
1	3	3 to 3.6.15	Ergonomics of control stations	New Section added	5
1	3 to 6			Existing Sections renumbered	5
1	3	3.1.1	Unattended machinery space(s) – UMS notation	Reference amended	5
1	3	3.2.3	Unattended machinery space(s) – UMS notation	Existing paragraph renumbered, amended and reference amended	5
1	4	4.1.1	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.1.3	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.1.4	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.2.1	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	4	4.2.6	Machinery operated from a centralised control station – CCS notation	Reference amended	5
1	5	5.1.2	Requirements for craft which are not required to comply with the HSC Code	Reference amended	5
1	5	5.1.3	Requirements for craft which are not required to comply with the HSC Code	References amended	5
1	6	6.2.1	Trials	Reference amended	5
1	6	6.3.1	Trials	Reference amended	5
2	1	1.1.1	General requirements	References amended	5
2	1	1.2	General requirements	Sub-Section retitled	5
2	1	1.2.1	General requirements	Paragraph amended	5
2	1	1.2.3 to 1.2.4	General requirements	New paragraphs added	5
2	1	1.2.3 to 1.2.4	General requirements	Existing paragraphs renumbered	5
2	1	1.2.4	General requirements	Reference amended	5
2	1	1.2.6	General requirements	Reference amended	5
2	1	1.2.7	General requirements	New paragraph added	5
2	1	1.2.5 to 1.2.7	General requirements	Existing paragraphs renumbered	5
2	1	1.2.7	General requirements	Reference amended	5
2	1	1.2.8	General requirements	Existing paragraph renumbered and amended	5
2	1	1.2.9	General requirements	References amended	5
2	1	1.2.10	General requirements	Reference amended	5
2	1	1.2.12	General requirements	Existing paragraph renumbered	5
2	1	1.2.13	General requirements	Existing paragraph renumbered, amended and reference amended	5

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Ch	Section	Para	Section Title	Status	Notice
Part 16 (cont'd)				**Effective Date 1 January 2012**	
2	1	1.3 to 1.3.1	General requirements	New sub-Section title and paragraph added	5
2	1	1.2.10	General requirements	Existing paragraph renumbered	5
2	1	1.2.11	General requirements	Existing paragraph renumbered and amended	5
2	1	1.2.13	General requirements	Existing paragraph renumbered and amended	5
2	1	1.2.14	General requirements	Existing paragraph renumbered and reference amended	5
2	1	1.3 to 1.4	General requirements	Existing sub-Sections renumbered	5
2	1	1.3.4	General requirements	References amended	5
2	1	1.4.3	General requirements	References amended	5
2	1	1.4.4	General requirements	References amended	5
2	1	1.4.5	General requirements	References amended	5
2	1	1.5	General requirements	Existing sub-Section renumbered	5
2	1	1.5.3	General requirements	References amended	5
2	1	1.6.15 to 1.6.16	General requirements	New paragraphs added	5
2	1	1.6 to 1.9	General requirements	Existing sub-Sections renumbered	5
2	1	1.8.5	General requirements	Reference amended	5
2	1	1.8.6	General requirements	Reference amended	5
2	1	1.10	General requirements	Existing Sub-Section renumbered	5
2	1	1.10 to 1.10.7	General requirements	Existing paragraphs renumbered	5
2	1	1.10.1	General requirements	Reference amended	5
2	1	1.10.3	General requirements	References amended	5
2	1	1.10.4	General requirements	Reference amended	5
2	1	1.10.7	General requirements	Reference amended	5
2	1	1.10.12	General requirements	Reference amended	5
2	1	1.11.8	General requirements	New paragraph added	5
2	1	1.10.8 to 1.10.10	General requirements	Existing paragraphs renumbered	5
2	1	1.11.12	General requirements	New paragraph added	5
2	1	1.10.11 to 1.10.12	General requirements	Existing paragraphs renumbered	5
2	1	1.11	General requirements	Existing sub-Section renumbered	5
2	1	1.11.1 to 1.11.8	General requirements	Existing paragraphs renumbered	5
2	1	1.11.1	General requirements	Reference amended	5
2	1	1.11.2	General requirements	Reference amended	5
2	1	1.11.4	General requirements	Reference amended	5
2	1	11.1.6	General requirements	Reference amended	5
2	1	1.11.9	General requirements	Existing paragraph renumbered and amended	5
2	1	1.12	General requirements	Existing sub-Section renumbered	5
2	1	1.12.1 to 1.12.2	General requirements	Existing paragraphs renumbered	5
2	1	1.12.3	General requirements	Existing paragraph renumbered, amended and references amended	5
2	1	1.14 to 1.14.4	General requirements	New sub-Section added	5
2	1	Table 2.1.1	General requirements	New Table added	5
2	1	1.13	General requirements	Existing sub-Section renumbered	5
2	1	1.13.1	General requirements	Existing paragraph renumbered and amended	5
2	1	1.13.2 to 1.13.4	General requirements	Existing paragraphs renumbered	5
2	1	1.13.3	General requirements	Reference amended	5
2	1	1.13.4	General requirements	Reference amended	5
2	1	1.14	General requirements	Existing sub-Section renumbered	5
2	1	1.14.1	General requirements	Existing paragraph renumbered, amended and reference amended	5
2	1	1.14.2	General requirements	Reference amended	5
2	1	1.14.4	General requirements	Reference amended	5
2	1	1.15 to 1.16	General requirements	Existing sub-Sections renumbered	5
2	1	1.15.2	General requirements	Reference amended	5
2	1	1.16.2	General requirements	Reference amended	5
2	2	2.2.3	Main source of electrical power	Reference amended	5
2	2	2.4.1	Main source of electrical power	Reference amended	5
2	3	3.1.1	Emergency source of electrical power	Reference amended	5
2	3	3.2.7	Emergency source of electrical power	Reference amended	5
2	5	5.4.1	Supply and distribution	Paragraph amended	5

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Ch	Section	Para	Section Title	Status	Notice
Part 16 (cont'd)				**Effective Date 1 January 2012**	
2	5	5.7.4	Supply and distribution	Reference amended	5
2	5	5.8.1	Supply and distribution	Reference amended	5
2	6	6.1.4	System design – Protection	References amended	5
2	6	6.1.7	System design – Protection	Reference amended	5
2	6	6.9.1	System design – Protection	Reference amended	5
2	6	6.11.1	System design – Protection	Reference amended	5
2	7	7.1.1	Switchgear and control gear assemblies	Paragraph amended	5
2	7	7.5.3	Switchgear and control gear assemblies	Paragraph deleted	5
2	7	7.5.3 to 7.5.6	Switchgear and control gear assemblies	New paragraphs added	5
2	7	7.8.2	Switchgear and control gear assemblies	New paragraph added	5
2	7	7.12.5	Switchgear and control gear assemblies	New paragraph added	5
2	7	7.18.2	Switchgear and control gear assemblies	Reference amended	5
2	7	Table 2.7.1	Switchgear and control gear assemblies	Table deleted	5
2	7	Tables 2.7.1-2	Switchgear and control gear assemblies	New Tables added	5
2	8	8 to 8.4.1	Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures	New Section added	5
2	8 to 20			Existing Sections renumbered	5
2	8	8.1.2	Rotating machines	Reference amended	5
2	8	8.1.6	Rotating machines	Reference amended	5
2	8	8.2.1	Rotating machines	Reference amended	5
2	8	8.3.1	Rotating machines	References amended	5
2	8	8.3.2	Rotating machines	Reference amended	5
2	8	8.3.3	Rotating machines	Reference amended	5
2	8	8.8.3	Rotating machines	Reference amended	5
2	8	Table 2.8.1	Rotating machines	Reference amended	5
2	9	9.1.1	Converter equipment	Reference amended	5
2	9	9.1.2	Converter equipment	Reference amended	5
2	9	9.1.4	Converter equipment	Reference amended	5
2	9	9.1.6	Converter equipment	Reference amended	5
2	9	9.1.12	Converter equipment	References amended	5
2	9	9.2.1	Converter equipment	Reference amended	5
2	9	9.2.2	Converter equipment	Reference amended	5
2	9	9.2.11	Converter equipment	Reference amended	5
2	9	9.2.16	Converter equipment	Reference amended	5
2	9	9.2.18	Converter equipment	Reference amended	5
2	9	9.3.1	Converter equipment	Reference amended	5
2	9	9.3.8	Converter equipment	Reference amended	5
2	9	9.3.10	Converter equipment	Reference amended	5
2	9	9.3.12	Converter equipment	Reference amended	5
2	10	10.1.1	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.1.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.2.1	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.2.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.3.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.4.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5

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Ch	Section	Para	Section Title	Status	Notice
Part 16 (cont'd)				**Effective Date 1 January 2012**	
2	10	10.4.3	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.5.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.5.5	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.6.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.6.3	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.6.4	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.6.5	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.6.6	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.7.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.7.3	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.8.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.10	Electrical cables and busbar trunking systems (busways)	Paragraph deleted	5
2	10	10.8.11 to 10.8.22	Electrical cables and busbar trunking systems (busways)	Existing paragraphs renumbered	5
2	10	10.8.14	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.18	Electrical cables and busbar trunking systems (busways)	References amended	5
2	10	10.8.19	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.20	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.21	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.8.22	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.9.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.10.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.10.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.10.4	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.12.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.15.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.16.1	Electrical cables and busbar trunking systems (busways)	Existing paragraph renumbered and amended	5
2	10	10.16.3	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.17.1	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.17.2	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	10	10.17.4	Electrical cables and busbar trunking systems (busways)	Reference amended	5
2	11	11.3.4	Batteries	References amended	5

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Part 16 (cont'd)				**Effective Date 1 January 2012**	
2	11	11.3.5	Batteries	References amended	5
2	11	11.3.10	Batteries	Existing paragraph renumbered, amended and reference amended	5
2	11	11.3.11	Batteries	Reference amended	5
2	11	11.5.1	Batteries	Reference amended	5
2	11	11.5.5	Batteries	Reference amended	5
2	11	11.5.6	Batteries	References amended	5
2	11	11.5.11	Batteries	Reference amended	5
2	11	11.7.2	Batteries	Reference amended	5
2	11	11.7.3	Batteries	Reference amended	5
2	12	12.3.1	Equipment – Heating, lighting and accessories	Reference amended	5
2	12	12.4.1	Equipment – Heating, lighting and accessories	Reference amended	5
2	14	14.1.1	Navigation and manoeuvring systems	Reference amended	5
2	14	14.1.6	Navigation and manoeuvring systems	Reference amended	5
2	14	14.3.5	Navigation and manoeuvring systems	References amended	5
2	14	14.3.6	Navigation and manoeuvring systems	Reference amended	5
2	14	14.3.7	Navigation and manoeuvring systems	Reference amended	5
2	14	14.3.8	Navigation and manoeuvring systems	References amended	5
2	14	14.3.9	Navigation and manoeuvring systems	Reference amended	5
2	16	17.1.1	Fire safety systems	New paragraph added	5
2	16	16.1.1 to 16.1.7	Fire safety systems	Existing paragraphs renumbered	5
2	16	16.1.1	Fire safety systems	Reference amended	5
2	16	16.1.2	Fire safety systems	References amended	5
2	16	16.1.6	Fire safety systems	Reference amended	5
2	16	16.1.8	Fire safety systems	Existing paragraph renumbered and amended	5
2	16	16.1.9 to 16.1.18	Fire safety systems	Existing paragraphs renumbered	5
2	16	16.1.12	Fire safety systems	Reference amended	5
2	16	16.1.19 to 16.1.20	Fire safety systems	Paragraphs deleted	5
2	16	16.3.3	Fire safety systems	References amended	5
2	16	16.3.5	Fire safety systems	Reference amended	5
2	16	16.3.8	Fire safety systems	Reference amended	5
2	16	16.3.9	Fire safety systems	References amended	5
2	16	16.3.10	Fire safety systems	Reference amended	5
2	16	16.3.11	Fire safety systems	Reference amended	5
2	16	16.6.3	Fire safety systems	Reference amended	5
2	16	16.6.4	Fire safety systems	Reference amended	5
2	16	16.6.5	Fire safety systems	Reference amended	5
2	16	16.6.10	Fire safety systems	Reference amended	5
2	16	16.6.12	Fire safety systems	Reference amended	5
2	16	16.7.1	Fire safety systems	References amended	5
2	16	16.9.1	Fire safety systems	References amended	5
2	17	17.1.3	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.2.1	Crew and passenger emergency safety systems	References amended	5
2	17	17.2.2	Crew and passenger emergency safety systems	References amended	5
2	17	17.2.6	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.3.2	Crew and passenger emergency safety systems	References amended	5

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Ch	Section	Para	Section Title	Status	Notice
Part 16 (cont'd)				**Effective Date 1 January 2012**	
2	17	17.3.9	Crew and passenger emergency safety systems	References amended	5
2	17	17.3.11	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.4.2	Crew and passenger emergency safety systems	Reference amended	5
2	17	17.4.3	Crew and passenger emergency safety systems	References amended	5
2	18	18.2.2	Craft safety systems	Reference amended	5
2	19	19.2.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	References amended	5
2	19	19.2.5	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.3.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.7.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.7.2	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.10.2	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.10.4	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	References amended	5
2	19	19.11.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5

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Ch	Section	Para	Section Title	Status	Notice
Part 16 (cont'd)					**Effective Date 1 January 2012**
2	19	19.14.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	Reference amended	5
2	19	19.15.1	Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt	References amended	5
2	20	20.1.1	Testing and trials	Reference amended	5
2	20	20.1.2	Testing and trials	Reference amended	5
2	20	20.1.4	Testing and trials	Reference amended	5
2	20	202.2.1	Testing and trials	Reference amended	5
2	20	20.2.2	Testing and trials	Reference amended	5
2	20	20.2.3	Testing and trials	References amended	5
2	20	20.2.4	Testing and trials	Existing paragraph renumbered and amended	5
2	20	20.2.5	Testing and trials	Paragraph deleted	5
2	20	21.2.5	Testing and trials	New paragraph added	5

Ch	Section	Para	Section Title	Status	Notice
Part 16					**Effective Date 1 July 2012**
2	11	11.5.1 to 11.5.2	Batteries	Paragraphs amended	4

Ch	Section	Para	Section Title	Status	Notice
Part17					**Effective Date 1 July 2012**
1	1	1.1.2	General requirements	Paragraph amended	5
3	2	2.4.2	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	2	2.8.1	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	2	2.8.7	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	2	2.20.1	Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt	Reference amended	5
3	3	3.16.11	Fire safety measures for yachts 500 gt or more	Reference amended	5
3	3	3.24.5	Fire safety measures for yachts 500 gt or more	Reference amended	5
3	3	3.34.1	Fire safety measures for yachts 500 gt or more	Reference amended	5
4	1	1.2.1	Automatic sprinkler, fire detection and fire-alarm systems	Reference amended	5
4	2	2.1.2	Fixed fire detection and fire-alarm systems	Reference amended	5

Notice – Summary of Changes

CORRIGENDA

Ch	*Section*	*Para*	*Section Title*	*Status*	*Notice*
Rules for the Manufacture, Testing and Certification of Materials					
3	9	Table 3.9.3	Bars for welded chain cables	Table amended	1
4	2	Table 4.2.2	Castings for ship and other structural applications	Table amended	1
5	4	Table 5.4.3	Forgings for crankshafts	Table amended	1
5	4	Table 5.4.5	Forgings for crankshafts	Table amended	1
12	4	Table 12.4.10	Welding procedure tests for non-ferrous alloys	Table amended	1

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Rules and Regulations for the Classification of Special Service Craft

Volume 1
Part 1
Regulations
July 2012

Lloyd's Register
LIFE MATTERS

A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Special Service Craft

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).
(b) In same Part but different Chapter, e.g. *see* Ch 3,2.1 (i.e. down to sub-Section).
(c) In another Part, e.g. *see* Pt 5, Ch 1,3 (i.e. down to Section).

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).
(b) In same Part but different Chapter, e.g. as shown in Fig. 2.3.5 in Chapter 2.
(c) In another Part, e.g. *see* Table 2.7.1 in Pt 3, Ch 2.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

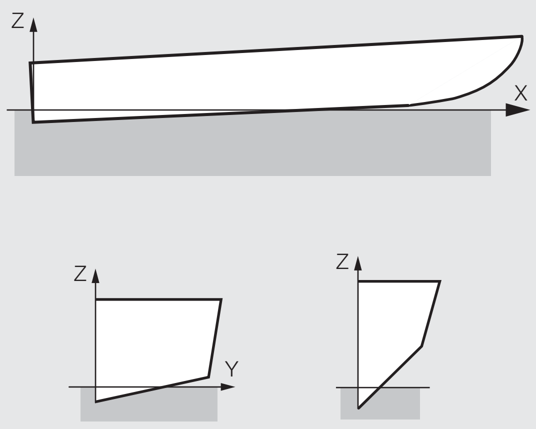
Direct calculations

The Rules require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

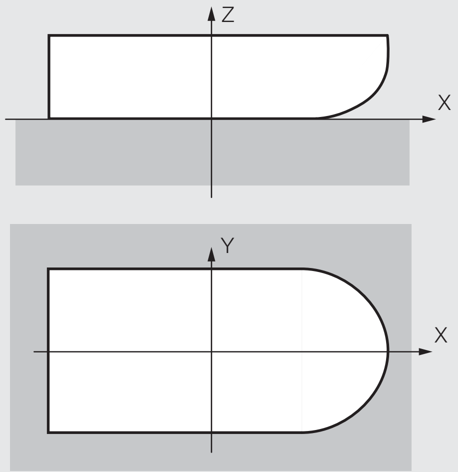
July 2012

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

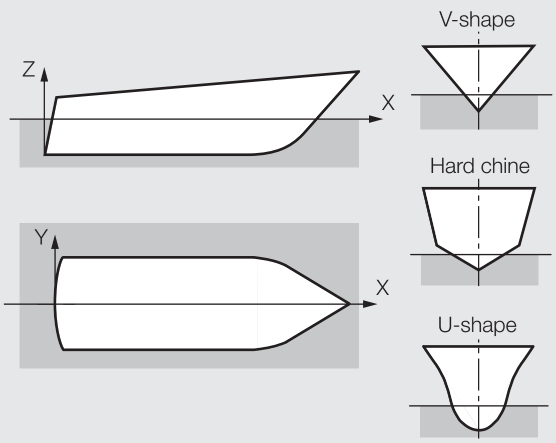
PLANING CRAFT



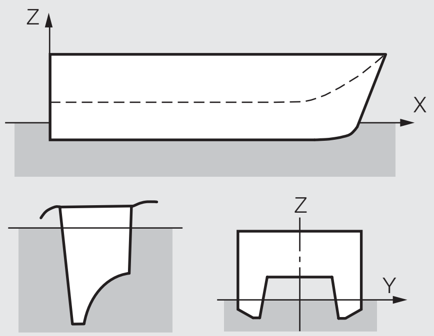
HOVERCRAFT



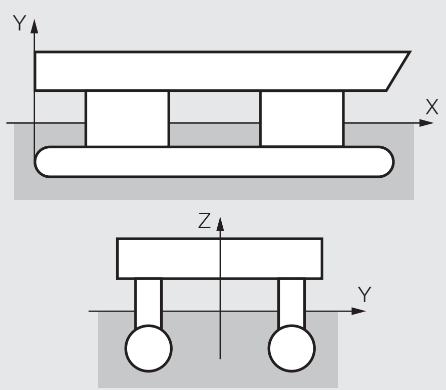
DISPLACEMENT CRAFT



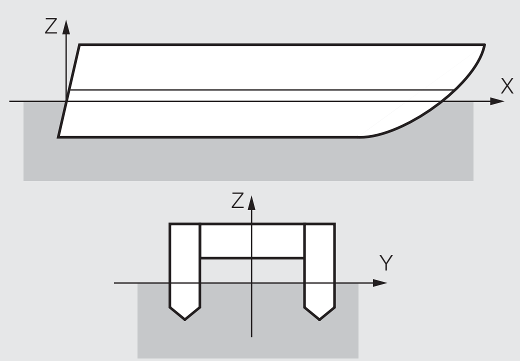
SURFACE EFFECT SHIP



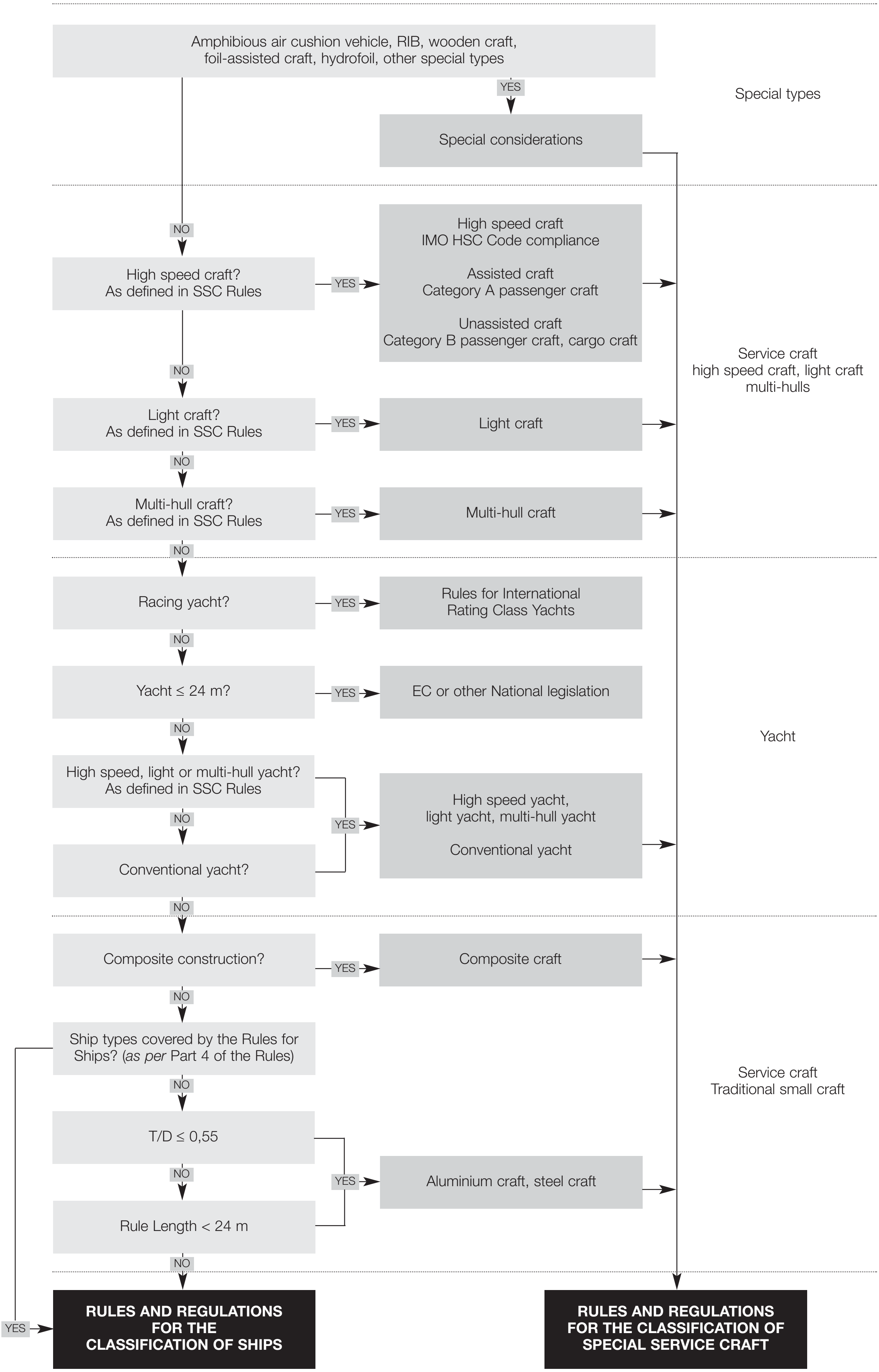
SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Part 1

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Section 1

1.1 Lloyd's Register (hereinafter referred to as 'LR'), which is recognised under the laws of the United Kingdom as a corporate body and a charity established for the benefit of the community, was founded in 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members of the Lloyd's Register Group, including: Lloyd's Register EMEA, Lloyd's Register Asia, Lloyd's Register North America, Inc., and Lloyd's Register Central and South America Limited.

1.3 The Lloyd's Register Group (hereinafter referred to as 'the LR Group') comprises charities, other forms of organisation and non-charitable companies, with the latter supporting the charities in their main goal of enhancing the safety of life and property, at sea, on land and in the air, for the benefit of the public and the environment.

Section 2

2.1 LR remains the sole classification society in the LR Group. LR is managed by a Board of Trustees (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;

appointed Technical Committees and determined their powers, functions and duties.

2.2 The LR Group has established National and Area Committees in the following:

Countries:
Australia (via Lloyd's Register Asia)
Canada (via Lloyd's Register North America, Inc.)
China (via Lloyd's Register Asia)
Egypt (via Lloyd's Register EMEA)
Federal Republic of Germany
(via Lloyd's Register EMEA)
France (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)
Japan (via Lloyd's Register)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

Areas:
Benelux (via Lloyd's Register EMEA)
Central America (via Lloyd's Register Central and South America Ltd)
Nordic Countries (via Lloyd's Register EMEA)
South Asia (via Lloyd's Register Asia)
Asian Shipowners (via Lloyd's Register Asia)
Greece (via Lloyd's Register EMEA)

Section 3

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:
Ex officio members:
- Chairman and Chief Executive Officer of LR
- Chairman of the Classification Committee of LR

Members Nominated by:
- Technical Committee
- Royal Institution of Naval Architects ... 2
- Institution of Engineers and Shipbuilders in Scotland ... 2
- Institute of Marine, Engineering, Science and Technology ... 2
- Institute of Materials, Minerals and Mining ... 1
- Honourable Company of Master Mariners ... 2
- Institution of Engineering and Technology ... 1
- Institute of Refrigeration ... 1
- Welding Institute ... 1
- Shipbuilders' and Shiprepairers' Association ... 2
- The Society of Consulting Marine Engineers and Ship Surveyors
- Community of European Shipyards Associations ... 1
- Society of Maritime Industries ... 2
- European Marine Equipment Council ... 1
- Chamber of Shipping ... 1
- Greek Shipping Co-operation Committee ... 1
- International Association of Oil and Gas Producers ... 1

3.2 In addition to the foregoing:
(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.
(b) A maximum of five representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee under one of the categories identified in 3.1.
(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:
(a) any technical issues connected with LR's marine business;
(b) any proposed alterations in the existing Rules;
(c) any new Rules for classification;
Where changes to the Rules are necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies these may be implemented by LR without consideration by the Technical Committee.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than Part 1, Chapter 1, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:
(a) appoint sub-Committees or panels; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:
Ex officio members
- Chairman and Chief Executive Officer of LR

Member nominated by:
- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee Chairman is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, Part 1, Chapter 1 of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than Part 1, Chapter 1, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:
(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 5*

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:
(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.
(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of ‘contract for construction’ of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of ‘contract for construction’ of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a ‘series of sister ships’ is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date

on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

■ *Section 6*

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

■ *Section 7*

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

■ *Section 8*

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, the LR Group does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of any of the LR Group or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR's services or relies on any information or advice given by or on behalf of the LR Group and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of the LR Group or any negligent inaccuracy in information or advice given by or on behalf of the LR Group, then a member of the LR Group will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 Notwithstanding the previous clause, the LR Group will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of the LR Group even if held to amount to a breach of warranty.

8.4 Any dispute about LR's services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section 1
Conditions for classification

1.1 General

1.1.1 The *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft), are applicable to those types of craft which are defined in 2.1. Where the word craft is used in the text of the Rules, it is to be taken as being applicable to yachts and other craft as stated herein unless specifically indicated otherwise.

1.1.2 The Rules are framed on the understanding:

(a) that the craft will at all times be properly loaded. They do not, unless stated or implied in the class notation, provide for special distributions or concentrations of loading associated with the operation of the craft. Lloyd's Register (hereinafter referred to 'LR') may require additional strengthening to be fitted in any craft, which, in their opinion, would otherwise be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration,

(b) that the craft will at all times be properly handled, with particular reference to the placing on board of persons and equipment and the reduction of speed in heavy weather,

(c) that compliance with the Rules does not relieve the designer of his responsibilities to his client for compliance with the specification and the requirements for the overall design and in service performance of the craft,

(d) that the craft will not be operated outside of the para-meters specified in any operational envelope which may have been assigned, without the prior agreement of LR.

1.1.3 New craft built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a class in the appropriate *Register Book* and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules. Classification will be conditional upon compliance with LR's requirements for both hull and machinery.

1.1.4 The class notations of yachts will be recorded on the ClassDirect Live website. The class notations of other craft will be recorded on the ClassDirect Live website in the *Register of Ships.*

1.1.5 LR, in addition to requiring compliance with the Rules, will, in general, require to be satisfied that craft are suitable for the geographical or other limits or conditions of the service contemplated.

1.1.6 Loading conditions and any other preparations required to permit a craft with a notation specifying some service limitation to undertake a sea-going voyage, either from port of building to service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which could invalidate the conditions for which a class has been assigned, is to be reported to LR without delay. Any detention or arrest is also to be reported to LR without delay.

1.1.8 Where the provision of loading or stress monitoring equipment has been required by LR as the result of local, longitudinal or transverse strength calculations and the imposition of operating limitations, the necessary loading guidance information and operating instructions are to be incorporated in the relevant manuals supplied to the Master.

1.1.9 Where an onboard computer system having longitudinal strength computation capability, which is required by the Rules, is provided on a new craft, or newly installed on an existing craft, then the system is to be certified in respect of longitudinal strength use in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.*

1.1.10 Where an onboard computer system having stability computation capability is provided on a new craft, then the system is to be certified in respect of stability aspects in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs*. When provided, an onboard computer system having stability computation capability is to carry out the calculations and checks necessary to assess compliance with all the stability requirements applicable to the craft on which it is installed.

1.1.11 For craft, the arrangements and equipment of which are required to comply with the requirements of the:

- *International Convention on Load Lines, 1966*:
- *International Convention for the Safety of Life at Sea, 1974* and its protocol of 1978, which includes the *International Code of Safety for High Speed Craft*:
- *International Convention for the Prevention of Pollution from ships, 1974*, as modified by the Protocol of 1978 relating thereto:

and applicable Amendments thereto, the Committee requires the applicable Convention Certificates to be issued by a National Administration, or by LR, or by an IACS Member when so authorised. Safety Management Certificates in accordance with the provisions of the *International Safety Management Code* (ISM Code) may be issued by an organisation complying with IMO Resolution A.739(18) and authorised by the National Authority with which the craft is registered. Cargo Ship Radio Certificates may be issued by an organisation authorised by the National Authority with which the craft is registered.

1.1.12 In the case of dual classed craft, Convention certificates may be issued by the other classification society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other classification society is also authorised by the National Authority.

1.1.13 Yachts with a load line length, of 24m and over, having a service type notation of Yacht, will be assigned class only after it has been demonstrated that the stability of the yacht complies with the stability requirements of the National Administration, provided these are as a minimum equivalent to the intact stability requirements of the UK MCA LY2 Code (as amended).

1.1.14 Yachts with a load line length of 24 m and above, and with a gross tonnage of less than 3000, will be assigned a service type notation Yacht(S) only after it has been demonstrated that both the intact and damage stability comply with the UK MCA LY2 Code.

1.1.15 Yachts with a load line length of 24 m and above, and with a gross tonnage of 3000 and above, will be assigned a service type notation Yacht(S) only after it has been demonstrated that both the intact and damage stability comply with enhanced stability requirements such as a recognised International Standard.

1.2 Application

1.2.1 Except in the case of a special directive by the Committee, no new Regulation or alteration to any existing Regulation relating to character of classification or to class notations is to be applied to existing craft.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Scope of classification

1.4.1 Classification covers the structural design, watertight integrity and standard of construction of the hull and construction, installation and testing of the propulsion machinery, essential auxiliary machinery, essential piping and electrical systems to the extent indicated within these Rules.

1.4.2 Outfit, other than that covered by 1.4.1, general finish, noise levels, vibration (other than shaft vibration where applicable), trim, design speed and stability, except as mentioned in 1.1.11, 1.1.13 and 1.1.14 are outside the scope of classification.

1.4.3 Where a craft is to be fitted with sails, the masts, rigging and sail arrangements are left to the judgment and experience of the Owner, the Builders and the designers, and LR does not accept responsibility for them. However, for classification purposes the attending Surveyor must be satisfied that they are being maintained in a satisfactory condition.

1.4.4 Where a craft is so badly damaged that class has to be suspended, LR is prepared to assist the Owner with advice if requested.

1.4.5 The attention of Owners and Builders is drawn to statutory requirements which may be imposed by the relevant National Administration and which may not be within the scope of classification.

1.5 Client's responsibilities

1.5.1 The Client is to give LR's Surveyors every facility and necessary access to carry out their survey duties. The Client should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.5.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey, and LR's Surveyors will not be in continual attendance at LR's Client's premises. As construction and outfitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors have been complied with.

Section 2
Scope of the Rules

2.1 Applicable craft types

2.1.1 The Rules are applicable to the following craft types constructed from steel, aluminium alloy, composite materials or combinations of these materials:
(a) High speed craft.
(b) Light displacement craft.
(c) Multi-hull craft.
(d) Yachts of overall length, L_{OA}, 24 m or greater.
(e) Craft with draught to depth ratio less than or equal to 0,55.

2.1.2 The following craft types will be considered upon request on the basis of the Rules:
(a) Amphibious air cushion vehicles.
(b) Rigid inflatable boats.
(c) Hydrofoil craft.
(d) Foil assisted craft.
(e) Craft as defined 2.1.1(a) to (e) constructed from wood or wood/composite combinations.
(f) Other craft constructed from composite materials.
(g) Craft with a Rule length, L_R, less than 24 m and draught to depth ratio greater than 0,55.

2.1.3 Existing yachts, regardless of length, are subject to the survey requirements defined in Chapter 4.

2.1.4 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

2.1.5 At the discretion of LR craft types which are specifically covered by LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or other LR Rules and Regulations for Classification may be considered for classification in accordance with these Rules and Regulations.

2.1.6 Where any aspect of the design or construction is not covered by the Rules, the relevant requirements of the Rules for Ships or the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) will be applied as considered necessary.

2.2 Definitions

2.2.1 For the purpose of the Rules, the definitions given in 2.2.2 to 2.2.29 will apply.

2.2.2 **Air Cushion Vehicle.** An Air Cushion Vehicle (ACV) is a craft such that the whole or a significant part of its weight can be supported, whether at rest or in motion, by a continuously generated cushion of air dependent for its effectiveness on the proximity of the surface over which the craft operates.

2.2.3 **Assisted craft.** An assisted craft is any craft operating on a route where it has been demonstrated to the satisfaction of the Administrations concerned that there is a high probability that in the event of an evacuation at any point of the route, all passengers and crew can be rescued safely within the time specified in the HSC Code.

2.2.4 **Catamaran.** A catamaran is a craft with twin-hulls linked by a bridging structure.

2.2.5 **Composite materials.** Composite materials are those construction materials consisting principally of fibre reinforced plastics.

2.2.6 **Design waterline** is the waterline corresponding to the maximum operational weight of the craft with no lift or propulsion machinery active.

2.2.7 **Foil assisted craft.** A foil assisted craft is a craft designed such that a significant part of its weight, whilst in motion, is supported by hydrodynamic lift generated by foils.

2.2.8 **High speed craft.** A high speed craft is a craft capable of maximum speed, V, *see* 2.2.11, not less than:

$$V = 7{,}19\,\nabla^{1/6} \text{ knots}$$

where

∇ = moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.2.9 **Hydrofoil craft.** A hydrofoil craft is a craft which is supported above the water surface in non-displacement mode by hydrodynamic forces generated by foils.

2.2.10 **Light displacement craft.** A light displacement craft is a craft with a displacement not exceeding:

$$\Delta = 0{,}04(L_R B)^{1{,}5} \text{ tonnes}$$

where

L_R and B are defined in Pt 3, Ch 1.

2.2.11 **Maximum speed.** Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the craft is certified at maximum operational weight and in smooth water.

2.2.12 **Mono-hull craft.** A mono-hull craft is a craft whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.13 **Multi-hull craft.** A multi-hull craft is a craft with two or more hulls linked by a bridging structure which may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.14 **Operational speed.** Operational speed is the speed, in knots, corresponding to that permitted by the operational envelope. For High Speed Craft it is not more than 90 per cent of the maximum speed.

2.2.15 **Operational envelope.** The operational envelope defines the craft's service in terms of operational speeds, wave heights, displacements, service area and time required to seek refuge.

2.2.16 **Passenger.** A passenger is every person other than:

(a) The Master and the members of the crew or other persons employed or engaged in any capacity on board a craft on the business of that craft, and

(b) a child under one year of age.

2.2.17 **Passenger craft.** A passenger craft is a craft which carries more than twelve passengers.

2.2.18 **Patrol craft.** A patrol craft is a craft which may be operated by the harbour, police, customs, military authorities, search and rescue or similar organisations.

2.2.19 **Pilot launch.** A pilot launch is a craft designed to come alongside ships whilst at sea to embark or disembark pilots.

2.2.20 **Place of refuge.** A place of refuge is any naturally or artificially sheltered area which may be used as a shelter by a craft under conditions likely to endanger its safety.

2.2.21 **Range to refuge.** Range to refuge is the maximum allowable distance in nautical miles, measured along the shortest safe navigational track from any point on the intended voyage route of the craft to the nearest accessible harbour or place of refuge.

2.2.22 **Reasonable weather.** Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:

(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.

(b) Motions such as do not impair the efficient operation of the craft and do not significantly reduce passenger comfort or safety or impose any undue loads on any cargo carried.

2.2.23 **Rigid Inflatable Boat.** A Rigid Inflatable Boat (RIB) is a craft combining a rigid hull enclosed by a watertight self-draining deck situated above the deepest operational load waterline and provided with a gas, air or foam-filled flotation collar/fender at the edge of the deck above the hull to improve the stability and to augment the reserve of buoyancy and sea-keeping ability of the rigid hull.

2.2.24 **Service craft.** Service craft is any craft within the scope of the Rules other than a yacht or an amphibious air cushion vehicle.

2.2.25 **Small Waterplane Area Twin Hull Ship.** A Small Waterplane Area Twin Hull Ship (SWATH) is a twin-hulled craft characterised by bulbous lower hulls (torpedoes) and relatively narrow struts connecting them to the haunches and deck structure.

2.2.26 **Surface Effect Ship.** A Surface Effect Ship (SES) is an air-cushion vehicle whose cushion is totally or partially retained by permanently immersed rigid structures.

2.2.27 **Unassisted craft.** An unassisted craft is any craft other than an assisted craft, with machinery and safety systems arranged such that, in the event of damage disabling any essential machinery and safety systems in one compartment, the craft retains the capability to navigate safely as defined in the HSC Code.

2.2.28 **Wave piercer.** A wave piercer is a particular type of catamaran with lower hulls of a displacement or semi-displacement form that provide a positive freeboard when at rest in smooth water but which are expected to become partially submerged when advancing in waves.

2.2.29 **Yacht.** A yacht is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

2.2.30 **Workboat.** A workboat is a general purpose service craft which may be adapted for duties such as line handling, towing, tender, survey, fishing, oil spill recovery, or diving support.

■ *Section 3* Character of classification and class notations

3.1 General

3.1.1 This Section details the character symbols and notations which comprise the class assigned to special service craft.

3.1.2 The operational envelope assigned to craft built and classed in accordance with the Rules will be included in the operational manual of the craft where such a manual is required by the Rules. A reference to the operational envelope will be made in the Classification Certificate.

3.1.3 Craft built and classed in accordance with the Rules for restricted service but which are not assigned an operational envelope will have their geographical limits included in the Classification Certificate.

3.2 Character symbols

3.2.1 All craft, when classed, will be assigned a character of classification comprising one or more character symbols as applicable, e.g. **✠100A1 SSC.**

3.2.2 A full list of character symbols for which craft may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey, in compliance with the Rules, and to the satisfaction of the Committee.

$\overline{✠}$ This distinguishing mark will be assigned, at the time of classing, to new craft constructed under LR's Special Survey in accordance with plans approved by another recognised classification society.

100 This character figure will be assigned to all craft considered suitable for sea-going service except those in Service Group 1, *see* 3.5.5.

A This character letter will be assigned to all craft which have been built or accepted into class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:
- (a) Craft having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.
- (b) Craft classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Committee as suitable and sufficient for the particular service.

N This character letter will be assigned to craft on which the Committee has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

T This character letter will be assigned to ships which are intended to perform their primary designed service function only while they are anchored, moored, towed or linked, and which have, in good and efficient condition, adequately attached anchoring, mooring, towing or linking equipment which has been approved by the Committee as suitable and sufficient for the intended service.

SSC These character letters will be assigned to craft indicating that the craft has been constructed or accepted into class on the basis of the Rules.

3.2.3 For classification purposes the character figure **1** or the character letter **N** is to be assigned.

3.2.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the class of the craft will be liable to be withheld.

3.3 Class notations (hull)

3.3.1 When considered necessary by the Committee, or when requested by an Owner and agreed by the Committee, a class notation will be appended to the character of classification assigned to the craft. The class notation will consist of one of, or a combination of:
- (a) a high speed craft notation;
- (b) a light displacement craft notation;
- (c) a service area restriction notation;
- (d) a service type notation; and
- (e) a craft type notation;
- (f) other hull notations;

e.g.

✠100A1 SSC Passenger (A) Catamaran HSC G3 'service area'

✠100A1 SSC Yacht Catamaran LDC G5.

3.3.2 A list of class notations (hull) for which a craft may be eligible is given in 3.4 to 3.10.

3.4 High speed craft and light displacement craft notations

3.4.1 **HSC – High speed craft notation.** This class notation will be assigned to high speed craft as defined in 2.2.8.

3.4.2 **LDC – Light displacement craft notation.** This class notation will be assigned to light displacement craft as defined in 2.2.10.

3.5 Service area restriction notations

3.5.1 All craft classed under the Rules will be assigned a service area restriction notation **G** followed by a number e.g. **G1.** Craft classed under the Rules for service groups **G1** to **G5** are not suitable for unrestricted service except as noted in the service area restriction notation, *see* 3.5.5.

3.5.2 Service area restriction notations, given in 3.5.5, are expressed in terms of range to refuge in nautical miles as defined in 2.2.20.

3.5.3 Where craft are required to satisfy limitations in respect of the maximum duration of time to a place of refuge from any point during the voyage, this time is to be determined by dividing the range to refuge by the permitted operational speed of the craft (when fully laden) in the prevailing conditions as imposed by the operational envelope.

3.5.4 For craft that are designed in accordance with an operational envelope, typically **HSC** or **LDC** craft as defined in 3.4:
- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate such that the limits of the operational envelope are exceeded.

For craft that are not assigned an operational envelope:
- these craft are to be operated at reduced speeds and are to seek calmer waters or refuge when the weather conditions deteriorate or are predicted to deteriorate.

All craft are to be aware of the weather forecast for the proposed and current areas of operation and area of refuge.

3.5.5 The service area restriction notations defined below describe the service area restriction for which the craft has been approved and constructed.

G1 **Service Group 1** covers craft intended for service in sheltered waters adjacent to sandbanks, estuaries, reefs, breakwaters or other coastal features and in similarly sheltered waters between islands in reasonable weather where the range to refuge is, in general, five nautical miles or less. The geographical limits of the intended service are to be identified by the Builder and agreed with LR. Craft in this group are not eligible for the assignment of the character figure **100.**

G2 **Service Group 2** covers craft intended for service in reasonable weather, in waters where the range to refuge is 20 nautical miles or less. This group will usually cover craft intended for service in coastal waters, for which geographical limits are to be identified by the Builder and agreed with LR.

G2A **Service Group 2A** covers craft intended for service in reasonable weather in waters where the range to refuge is 60 nautical miles or less. The geographical limits of the intended service are to be reported to LR. Craft in this group are eligible for assignment of the service type notation **SRY**.

G3 **Service Group 3** covers craft intended for service in waters where the range to refuge is 150 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G4 **Service Group 4** covers craft intended for service in waters where the range to refuge is 250 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G5 **Service Group 5** covers craft intended for service in waters where the range to refuge is 350 nautical miles or less. The geographical limits of the intended service are to be reported to LR.

G6 **Service Group 6** covers yachts and steel patrol craft having unrestricted service.

3.5.6 Consideration may be given to requests for an increase in the permissible range to refuge subject to:

(a) The specific geographic limits and the period over which the extended service is to be operated being defined.
(b) Satisfactory statistical data in respect of wave height, being provided to demonstrate that the craft will be suitable for the extended service.
(c) Equipment consistent with that required for the extended service being provided onboard during the period of operation.
(d) Any maximum duration of voyage limitations imposed by 3.5.3 not being exceeded during the extended service.

3.6 Service type notations

3.6.1 The service type notation will be recorded in the appropriate *Register Book* indicating the primary purpose for which the craft has been designed and constructed.

3.6.2 A list of service type notations for which craft may be eligible is given below:

Cargo (A) This notation will be assigned to cargo craft other than Cargo (B) craft.

Cargo (B) This notation will be assigned to unassisted high speed cargo craft of 500 gross tons and over which do not proceed in the course of their voyage more than eight hours at operational speed from a place of refuge when fully laden. These craft correspond to ‘Cargo Craft’ as defined in the HSC Code.

Passenger This notation will be assigned to passenger craft other than **Passenger (A)** or **Passenger (B)** craft.

Passenger (A) This notation will be assigned to assisted high speed craft carrying not more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to ‘Category A Craft’ as defined in the HSC Code.

Passenger (B) This notation will be assigned to unassisted high speed craft which may carry more than 450 passengers on board and which do not proceed in the course of their voyage more than four hours at operational speed from a place of refuge when fully laden. These craft correspond to ‘Category B Craft’ as defined in the HSC Code.

Patrol This notation will be assigned to patrol craft complying with the relevant requirements of the Rules.

Pilot This notation will be assigned to pilot launches complying with the relevant requirements of the Rules.

Yacht or Support Yacht Craft This notation will be assigned to all yachts.

Workboat This notation will be assigned to workboats complying with the relevant requirements of the Rules.

3.7 Craft type notations

3.7.1 The craft type notation will be recorded in the appropriate *Register Book* indicating the type of hull form and mode of operation for which the craft has been designed and constructed.

3.7.2 A list of craft type notations for which craft may be eligible is given below:

ACV This notation will be assigned to amphibious air cushion vehicles.

Catamaran This notation will be assigned to catamarans including wave piercers.

Hydrofoil This notation will be assigned to hydrofoil craft.

Mono This notation will be assigned to mono-hull craft other than amphibious air cushion vehicles, hydrofoils and rigid inflatable boats.

Multi This notation will be assigned to multi-hull craft other than catamarans, swaths and surface effect ships.

RIB This notation will be assigned to rigid inflatable boats.

SES This notation will be assigned to surface effect ships.

Swath This notation will be assigned to small water-plane area twin hull ships.

3.7.3 Where craft indicated in 3.7.2 are foil assisted the letters (FA) may be appended to the Craft Type Notation.

3.8 Other hull notations

3.8.1 **Ice class notation.** A class notation for navigation in first-year ice conditions will be specially considered.

3.8.2 ***IWS.** This notation (In-water Survey) may be assigned to a craft where the applicable requirements of LR's Rules and Regulations are complied with. (*See* Ch 3,4.3 and Ch 4,3.3, *see also* Pt 3, Ch 3,2.37).

3.8.3 **Special features notation.** A notation indicating that the craft incorporates special features which significantly affect the design, e.g. movable decks.

3.8.4 **LI.** This notation will be assigned where an approved loading instrument has been installed as a classification requirement.

3.8.5 **SRY**. This notation will be assigned to Short-Range Yachts with service area restriction G2A and in accordance with the MCA *Large Commercial Yacht Code*, MSN 1792(M) requirements for Short-Range Yachts.

3.9 Class notations (machinery)

3.9.1 The following class notations may be assigned as considered appropriate by the Committee:

✠LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed, installed and tested under LR's Special Survey and in accordance with LR's Rules and Regulations.

$\overline{✠}$ LMC This notation will be assigned when the propelling and essential auxiliary machinery has been constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition, the whole of the machinery will be required to have been installed and tested under LR's Special Survey in accordance with LR's Rules and Regulations.

[✠]LMC This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for essential systems have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules and Regulations. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for essential services that are in compliance with LR Rules and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.2.

LMC This notation (without ✠) will be assigned when the propelling and essential auxiliary machinery has neither been constructed nor installed under LR's Special Survey but the existing machinery, its installation and arrangement, has been tested and found to be acceptable to LR. This notation is assigned to existing craft in service accepted or transferring into LR class.

MCH This notation will be assigned when the propelling and essential auxiliary machinery has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for essential services supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See* 3.10.1.

UMS This notation may be assigned when the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto and the arrangements are such that the craft can be operated with the machinery spaces unattended.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a centralised control station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR's Rules, or is equivalent thereto.

3.9.2 Machinery class notations will not be assigned to craft the hulls of which are not classed or intended to be classed with LR.

3.9.3 The notation **✠LMC**, **$\overline{✠}$ LMC, [✠]LMC**, **LMC** (without ✠) and **MCH** will in general not be assigned to non-propelled craft, but individual cases will be considered on their merits.

3.10 Application notes

3.10.1 Propelling and essential auxiliary machinery includes machinery, equipment and systems installed for the craft/yacht to be under seagoing conditions and that are necessary for the following:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety of the craft/yacht, machinery and personnel on board.
(c) The functioning and dependability of propulsion, steering and electrical systems.
(d) The operation and functioning of control engineering systems for the monitoring and safety of propulsion, steering and electrical power systems.
(e) The operation and functioning of emergency machinery and equipment.

3.10.2 **Manufacturer's certificate** for assignment of the **[✠]LMC** notation. Acceptance of the manufacturer's certificate for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht has a gross tonnage of less than 500, or has a gross tonnage of 500 or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The design and manufacturing standards for all machinery and associated systems are the applicable LR Rules.
(f) The machinery and equipment is manufactured under a recognised quality control system.
(g) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

3.10.3 **Manufacturer's certificate** for assignment of the **MCH** notation. Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery is subject to the following:

(a) For a craft: The craft is intended for the carriage of cargo (not passengers), is less than 500 gross tonnage or is of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a craft with unrestricted service.
(b) For a yacht: The yacht is less than 500 gross tonnage or is of 500 gross tonnage or more and is not required to comply with international conventions applicable to a yacht with unrestricted service.
(c) Propulsion power is provided by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(d) Electrical power is provided by generators driven by oil engines or gas turbines which have been type approved to LR requirements for marine application.
(e) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.
(f) The design and manufacturing standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(g) The machinery and equipment is manufactured under a recognised quality control system.

3.11 Class notations (Environmental Protection)

3.11.1 The following class notations are associated with the design and operation of a Special Service Craft and may be assigned as considered appropriate by the Committee, on application from the Owners:

EP This notation may be assigned when the design and operation of a Special Service Craft are in accordance with the relevant requirements in Pt 7, Ch 11 of the Rules.

$\overline{\textbf{EP}}$ This notation may be assigned when the environmental protection provisions of the Special Service Craft are in accordance with the requirements of another recognised classification society and are broadly equivalent to the requirements in Pt 7, Ch 11 of the Rules. Prior to assignment of the notation, an audit, in accordance with the requirements in 4.1.3 and 4.1.4 of Pt 7, Ch 11 of the Rules, is to be undertaken by LR to confirm that the necessary Environmental Protection procedures are in place and implemented effectively.

3.12 Descriptive notes

3.12.1 In addition to any class notations, an appropriate descriptive note may be entered in column 6 of the appropriate *Register Book* indicating the type of craft in greater detail than is contained in the class notation, and/or providing additional information about the craft's design and construction. This descriptive note is not a LR classification notation and is provided solely for the information of users of the *Register Book*.

3.12.2 The descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned when oil lubricated screwshaft arrangements with approved oil glands are fitted and the requirements of Ch 3,11.3 or Ch 4,10.3 are complied with.

Section 4 Surveys – General

4.1 Statutory surveys

4.1.1 The Committee will act, when authorised on behalf of Governments, in respect of National and International statutory safety and other requirements.

4.1.2 The Committee will also act, when authorised, in respect of National safety and other requirements relating to craft used for offshore mineral exploration and exploitation.

4.2 New construction surveys

4.2.1 When it is intended to build a craft for classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of the Committee before the work is commenced. Any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted for approval.

4.2.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of the Committee, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

4.2.3 The materials used in the construction of hulls and machinery intended for classification are to be of good quality and free from defects and are to comply with the requirements of the Rules.

4.2.4 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained both for the construction of the craft and the installation of machinery, electrical and control equipment.

4.2.5 In addition to 4.2.4, the hull construction of craft manufactured from composite materials is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures, *see* Pt 8, Ch 2.

4.2.6 New craft intended for classification are to be built under LR's Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be so, are to be rectified.

4.2.7 For compliance with 4.2.6 LR is prepared to consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems as defined in Chapter 2 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.2.8 Copies of approved plans (showing the craft as built), essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by LR's Surveyors and may be required to be kept on board.

4.2.9 After completion, the craft is to be examined afloat, and trials are to be conducted as specified in the Rules.

4.2.10 When the machinery is constructed under LR's Special Survey, this survey is to relate to the period from the commencement of the work until the final test under working conditions. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found to be unsatisfactory, are to be rectified.

4.2.11 When arrangements are such that essential machinery can be operated by remote and/or automatic control equipment, the control equipment is to be arranged, installed and tested in accordance with the Rules, as applicable.

4.2.12 The date of completion of the Special Survey during construction of craft built under LR's inspection will normally be taken as the date of build to be entered in the appropriate *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the appropriate *Register Book*.

4.2.13 When a craft, upon completion, is not immediately commissioned but is laid-up for a period, the Committee, upon application by the Owner, prior to the craft proceeding to sea, will direct an examination to be made by LR's Surveyors which may include a survey in dry-dock. If, as the result of such survey, the hull and machinery be reported in all respects free from deterioration, the subsequent Special Survey and Complete Survey of the machinery will date from the time of such examination.

4.3 Existing craft

4.3.1 **Classification of craft not built under survey.** The requirements of the Committee for the classification of craft which have not been built under LR's Survey are indicated in Ch 3,12 or Ch 4,12 as applicable. Special consideration will be given to craft transferring class to LR from another recognised Classification Society.

4.3.2 **Reclassification.** When reclassification or class reinstatement is desired for a craft for which the class previously assigned by LR has been withdrawn or suspended, the Committee will direct that a survey, appropriate to the age of the craft and the circumstances of the case, be carried out by LR's Surveyors. If, at such survey, the craft be found or placed in a good and efficient condition in accordance with the requirements of the Rules, the Committee will be prepared to consider reinstatement of the original class or the assignment of such other class as may be deemed necessary.

4.3.3 In the case of existing yachts over 15 years of age, the requirements for classification of craft not built under survey or for reclassification will be specially considered.

4.3.4 The Committee reserves the right to decline an application for classification or reclassification where the prior history or condition of the craft indicates this to be appropriate.

4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a craft may retain her class, *see* 1.1.7, are to be carried out to the satisfaction of LR's Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of LR's Surveyors at the earliest opportunity thereafter.

4.4.2 When at any survey the Surveyors consider repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the Committee by the Surveyors.

4.4.3 Where repairs are to be carried out by a riding crew during a voyage then these must be planned in advance. A complete repair procedure, including the extent of proposed repair and the need for Surveyor's attendance during the voyage, is to be submitted reasonably in advance to the Surveyor for agreement. Failure to notify LR in advance of the repairs may result in the class of the ship being specially considered by the Classification Committee. Where emergency repairs are effected immediately due to an emergency circumstance, the repairs should be documented in the ship's log and submitted thereafter to LR for use in determining further survey requirements.

4.4.4 When at any survey it is found that any damage, defect, or breakdown (*see* 1.1.7) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable condition of class is to be imposed by the Surveyors and recommended to the Committee for consideration.

4.4.5 If a craft which is classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.6 If a craft which is classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.7 Plans and particulars of any proposed alterations to the approved scantlings and arrangements of hull, equipment, or machinery are to be submitted for approval by Owners or Builders or their representatives and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.4.8 The Owners should notify LR whenever a craft can be examined in dry-dock or on a slipway.

4.5 Existing service craft and yachts – Periodical Surveys

4.5.1 Service craft are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.2 Yachts are to be submitted to the periodical survey requirements defined in Chapter 4, except in the case where LR issues Statutory Loadline SAFCON certification or Certificate of Compliance to 'Code of Practice' as a requirement of the National Authority of the country in which the yacht is registered. In these cases they are to be submitted to the periodical survey requirements as defined in Chapter 3.

4.5.3 Annual Surveys are to be held on all craft other than yachts within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded on the ClassDirect Live website.

4.5.4 Intermediate Surveys are to be held on all craft other than yachts instead of the second or third Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded on the ClassDirect Live website.

4.5.5 Intermediate Surveys are to be held on yachts between the second and third anniversary after completion, commissioning or Special Survey.

4.5.6 The Owner should notify the Surveyors whenever a craft can be examined in dry-dock or on a slipway. A minimum of two Docking Surveys are to be held in each five-year Special Survey period and the maximum interval between successive Docking Surveys is not to exceed three years. One of the two Docking Surveys required in each five year period is to coincide with the Special Survey. Consideration may be given at the discretion of the Committee to any special circumstances justifying an extension of this interval and the Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys, *see* Ch 3,4.3 and Ch 4,3.3. A Docking Survey is considered to coincide with the Special Survey when held within the 15 months prior to the due date of the Special Survey.

4.5.7 The interval between dry-dockings for craft operating in fresh water and for certain non self-propelled craft may at the discretion of the Committee, be greater than that given in 4.5.6.

4.5.8 Attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is registered.

4.5.9 The date of the last examination in dry-dock or on a slipway will be recorded on the ClassDirect Live website.

4.5.10 Survey requirements for In-water Surveys are given in Ch 3,4.3 and Ch 4,3.3 as appropriate. The date of the last In-water Survey will be recorded on the ClassDirect Live website.

4.5.11 All craft classed with LR are also to be subjected to Special Surveys. These Surveys become due at five-yearly

intervals, the first one five years from the date of build or date of Special Survey for Classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Special Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of the hull classification to a maximum of three months beyond the fifth year. If an extension is agreed the next period of hull classification will start from the due date of the Special Survey before the extension was granted.

4.5.12 Special surveys may be commenced at the fourth Annual Survey or fourth anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.13 Special Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee.

4.5.14 Craft which have satisfactorily passed a Special Survey will have a record entered indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the date recorded will be the fifth anniversary. In the case of yachts this information will be recorded on the ClassDirect Live website.

4.5.15 At the request of an Owner, the Committee may agree that the Special Survey of the hull be carried out on the Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of five years between consecutive examinations of each part. In general, approximately one fifth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the five year cycle. If the examination during Continuous Survey reveals any defects, further parts are to be opened up and examined as considered necessary by the Surveyor. For examination of items listed in Ch 3,2.2.17, 2.2.18, 3.2.2, 3.2.3, 3.2.4 or Ch 4,2.2.11, 2.2.12, 2.2.13 as applicable, the intervals for inspection will require to be specially agreed. Craft which have satisfactorily completed the cycle will have a record entered in the *Register Book* indicating the date of completion which will not be later than five years from the last assigned date of Complete Survey of the hull. The agreement for surveys to be carried out on Continuous Survey basis may be withdrawn at the discretion of the Committee.

4.5.16 Complete Surveys of machinery become due at five yearly intervals, the first one five years from the date of build or date of first classification as recorded in the appropriate *Register Book*, and thereafter five years from the date recorded for the previous Complete Survey. Consideration can be given at the discretion of the Committee to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the fifth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 15 months, except with the prior approval of the Committee. Where the complete survey is completed more than three months before the due date, the recorded date of completion will be the final date of survey. In all other cases the date recorded will be the fifth anniversary.

4.5.17 Upon application by an Owner, the Committee may agree to the extension of the survey requirements for main engines, which, by the nature of the craft's normal service, do not attain the number of running hours recommended by the engines' manufacturer for major overhauls within the survey periods given in 4.5.16.

4.5.18 If it is found desirable that any part of the machinery should be examined again before the due date of the next survey, a certificate for a limited period will be granted in accordance with the nature of the case.

4.5.19 When, at the request of an Owner, it has been agreed by the Committee that the Complete Survey of the machinery may be carried out on the Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed five years. In general, approximately one-fifth of the machinery is to be examined each year.

4.5.20 If any examination during Continuous Survey reveals defects, further parts are to be opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.21 Upon application by an Owner, The Committee may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the Chief Engineer of the craft at ports where LR is not represented, or, where practicable, at sea, followed by a limited confirmatory survey carried out at the next port of call where an Exclusive Surveyor is available. Particulars of this arrangement may be obtained from LR's Headquarters.

4.5.22 Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery as required by 4.5.21 may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may be obtained from any of LR's Offices.

4.5.23 Where condition monitoring equipment is fitted, the Committee, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.24 Screwshaft and Waterjet Unit Surveys are to be carried out as stated in Ch 3,11 for service craft and Ch 4,10 for yachts.

4.5.25 Boiler surveys and steam pipe surveys, where applicable are to be carried out as stated in accordance with Pt 1, Ch 3,15 and 16 of the Rules for Ships.

4.5.26 Craft of unusual design, type or arrangement may be subject to exceptional survey requirements. Such survey requirements will be detailed at the assignment of classification.

4.5.27 Where the Committee has agreed to an Owner's request to assign the notation 'laid-up', the vessel may be retained in class provided a satisfactory general examination of the hull and machinery is carried out at the Annual Survey/Intermediate Survey due date and in addition an Underwater Examination (UWE) is carried out at the Special Survey due date. The general examination may be carried out within three months before or after the Annual Survey due date.

4.6 Existing amphibious air cushion vehicles – Periodical Surveys

4.6.1 Amphibious Air Cushion Vehicles are to be submitted to the periodical survey requirements as defined in Chapter 5.

4.7 Certificates

4.7.1 When the required reports, on completion of the survey of new or existing craft which have been submitted for classification, have been received from the Surveyors and approved by the Committee, a certificate of First Entry of Classification, signed by the Chairman, or the Deputy Chairman and Chairman of the Sub-Committee of Classification, will be issued to Builders or Owners.

4.7.2 A Certificate of Class valid for five years subject to endorsement for Annual and/or Intermediate Surveys, as appropriate, will also be issued to the Owners.

4.7.3 LR's Surveyors are permitted to issue provisional (interim) certificates to enable a craft classed with LR to proceed on her voyage provided that in their opinion it is in a fit and efficient condition. Such certificates will embody the Surveyors' recommendations for continuance of class, but in all cases are subject to confirmation by the Committee.

4.8 Notice of surveys

4.8.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of class are carried out at the proper time and in accordance with the instructions of the Committee. Information is available to Owners on the ClassDirect Live website.

4.8.2 LR will give timely notice to an Owner about forthcoming surveys by means of a letter or a computer print-out of a craft's *Quarterly Listing of Surveys, Conditions of Class and Memoranda*. The omission of such notice, however, does not absolve the Owner from his responsibility to comply with LR's survey requirements for maintenance of class, all of which are available to Owners on the ClassDirect Live website.

4.9 Withdrawal/Suspension of class

4.9.1 When the class of a craft, for which the Regulation as regards surveys on hull, equipment and machinery have been complied with, is withdrawn by the Committee in consequence of a request from the Owner the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

4.9.2 When the Regulations as regards surveys on the hull, equipment or machinery have not been complied with and the craft is thereby not entitled to retain class, the class will be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation will be assigned.

4.9.3 Class will be automatically suspended and the Certificate of Class will become invalid if the Annual or Intermediate Survey, as appropriate, is not completed within three months of the due date of the survey.

4.9.4 Class will be automatically suspended from the expiry date of the Certificate of Class in the event that the Special Survey has not been completed by the due date and an extension has not been agreed (*see* 4.5.11), or is not under attendance by the Surveyors with a view to completion prior to resuming trading.

4.9.5 When in accordance with 4.4.4 a condition of class is imposed, this will be assigned a due date for completion and the craft's class will be subject to a suspension procedure if the condition of class is not dealt with, or postponed by agreement, by the due date.

4.9.6 When it is found, from the reported condition of the hull or equipment or machinery of a craft, that an Owner has failed to comply with Regulations 1.1.7, 1.1.11, 4.4.1 or 4.4.6 above, the class will be liable to be suspended or withdrawn, at the discretion of the Committee, and a corresponding notation assigned. When it is considered that an Owner's failure to comply with these requirements is sufficiently serious the suspension or withdrawal of class may be extended to include other craft controlled by the same Owner, at the discretion of the Committee.

4.9.7 When any craft proceeds to sea with less freeboard than that approved by the Committee, or when the freeboard marks are placed higher on the sides of the craft than the position assigned or approved by the Committee, or, in cases of craft where freeboards are not assigned, the draught is greater than that approved by the Committee, the class will be liable to be withdrawn or suspended.

4.9.8 When it is found that a craft is being operated in a manner contrary to that agreed at the time of classification, i.e. out with the parameters of the operational envelope, the class will be liable to be automatically withdrawn or suspended.

4.9.9 In all instances of class withdrawal or suspension, the assigned notation, with date of application, will appear in the *Register Book*. In cases where class has been suspended by the Committee and it becomes apparent that the Owners are no longer interested in retaining LR's class, the notation will be amended to withdrawn status. After class withdrawn status has been established in the appropriate *Register Book* for one year, it will be automatically amended to 'classed LR until' (with date). In the case of yachts this information will be recorded on the ClassDirect Live website.

4.9.10 For reclassification and reinstatement of class, *see* 4.3.2 and 4.3.3.

4.10 Survey of craft out of commission

4.10.1 The classification requirements for laid up vessels will be specially considered. Surveys for continuation of class may be required at the discretion of the Committee.

4.11 Appeal from Surveyors' recommendations

4.11.1 If the recommendations of LR's Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to the Committee, who may direct a Special Examination to be held.

■ *Section 5* IACS QSCS Audits

5.1 Audit of Surveys

5.1.1 The surveys required by the Regulations may be subject to audit in accordance with the requirements of the International Association of Classification Societies Quality System Certification Scheme.

■ *Section 6* Type Approval/Type testing/ Quality control system

6.1 LR Type Approval – Marine Applications

6.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

6.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to use Quality Control procedures and processes to ensure that each item delivered is in conformity with that which has been Type Tested.

6.1.3 The selective testing required by 6.1.2 is to include environmental testing applicable to the product's installation on board a craft or yacht classed or intended to be classed with LR.

6.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in craft/yachts classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

6.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Special Service Craft are fulfilled.

6.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with 6.3.

6.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

6.2 Type testing

6.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

6.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

6.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

6.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

6.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in compliance with the current testing standards.

6.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

6.3 Quality control system

6.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that is used to demonstrate that the quality requirements for a product are in accordance with declared standards.

6.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

6.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

6.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of a quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 7*
Classification of machinery for craft/yachts with [✠] LMC or MCH notation

7.1 General

7.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the build yard, Survey at the build yard and Periodical Surveys are to be in accordance with the requirements for craft/yacht built or accepted into class with the ✠**LMC** notation.

7.2 Appraisal and records

7.2.1 To facilitate survey and compilation of classification records, plans and information required for a craft/yacht being accepted into class with the ✠**LMC** notation are to be submitted for appraisal and information. Plans are not required where machinery and equipment has previously been type approved; in these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

7.3 Survey and inspection

7.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the **[✠]LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing and any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system certified by an IACS member or a Notified Body.

7.3.2 The installation and testing of machinery and equipment at the build yard which has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a craft/yacht having the ✠**LMC** notation.

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:
(a) Annual Surveys, as required by Ch 2,4.5.3.
(b) Intermediate Surveys as required by Ch 2,4.5.4.
(c) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(d) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(e) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 For vessels assigned the notation 'laid-up', in order to maintain the vessel in class a general examination of the hull and machinery is to be carried out in lieu of the Annual Survey/Intermediate Survey and in addition an Underwater Examination (UWE) is to be carried out in lieu of the Special Survey, *see* 2.1.3, 5.1.4 and 7.1.3.

1.1.3 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.4 For the frequency of surveys of screwshafts, tube shafts propellers and water jet units, *see* Section 11.

1.2 Surveys for damage or alterations

1.2.1 At any time when a craft is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed, the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any craft, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar craft classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed craft, Convention Certificates may be issued by the other Society with which the craft is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 **A Ballast tank** is a tank which is used solely for salt water ballast. A tank which is used for both cargo and salt water ballast will be treated as a salt water ballast tank when substantial corrosion has been found in that tank.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:
(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel craft is defined as follows:
GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

■ *Section 2*
Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.1.3 For vessels assigned the notation 'laid-up', in lieu of the normal Annual Survey requirements a general examination of the hull and machinery is to be carried out.

2.2 Annual Surveys

2.2.1 The Surveyor is to be satisfied regarding:
(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.
(b) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components, wires, chains, etc.
(c) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines; fittings and appliances for timber deck cargoes.
(d) The efficient condition of bilge level detection and alarm systems on craft assigned a **UMS** notation.

2.2.2 Any cargo hatch covers and coamings together with any cargo doors or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.
(a) Mechanically operated cargo hatch covers or doors are to be tested for tightness and to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms; tracks and wheels.
(b) Cargo hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

2.2.3 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable.

2.2.4 The watertight doors in watertight bulkheads, their indicators and alarms are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.5 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems, and verify that log book entries have been made in accordance with statutory requirements where applicable.

2.2.6 Where applicable, the Surveyor is to be satisfied regarding the freeboard marks on the craft's side.

2.2.7 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.8 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.9 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.10 The boilers, other pressure vessels and their appurtenances, including foundations, controls, high pressure and waste steam piping, and insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of boilers and other pressure vessels have been carried out as required by the Rules.

2.2.11 For boilers, the safety devices are to be tested, and the safety valves are to be operated using the relieving devices. For exhaust gas heated economisers/boilers, the safety valves are to be tested at sea by the Chief Engineer and details recorded in the log book.

2.2.12 The operation and maintenance records, repair history and feed water chemistry records of boilers are to be examined.

2.2.13 For other pressure vessels, the safety devices are to be examined.

2.2.14 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.15 For main propulsion, essential auxiliary and emergency machinery control engineering systems, a general examination of the equipment and arrangements is to be carried out. Records of modifications are to be made available for review by the attending Surveyor. The documentation required by Pt 6, Ch 1, including configuration management, are to be reviewed following system modifications. Satisfactory operation of the safety devices and control systems is to be verified. For craft having **UMS** or **CCS** notation, a general examination of the control engineering equipment required for these notations is also to be carried out.

2.2.16 For craft fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine and, where possible, this is to include a running test under load;
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems; and
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.2.17 For craft to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted;
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.
(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.18 For steel craft, the requirements of 3.2.2 and 5.4.2 regarding the survey of water ballast spaces, integral sanitary tanks and bilges are also to be complied with as applicable.

Section 3 Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with statutory annual or other relevant statutory surveys wherever practicable.

3.2 Intermediate Surveys

3.2.1 The requirements of Section 2 are to be complied with so far as applicable.

3.2.2 For steel craft a general examination of salt water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

(a) For all craft over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.

(b) For steel craft over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all craft over 10 years of age the anchors are to be partially lowered and raised using the windlass.

3.2.4 The electrical generating sets are to be examined under working conditions.

3.2.5 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc., are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

Section 4 Docking Surveys and In-water Surveys – Hull and machinery requirements

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the craft and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

4.2 Docking Surveys

4.2.1 Where a craft is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.

(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.

(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

4.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

4.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

4.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

4.2.8 The clearance in the sternbush or the efficiency of the oil glands is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

4.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

4.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

4.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

4.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

4.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

4.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 5.3.7 and Table 3.5.1.

4.2.15 For SES craft any flexible skirts together with their attachment are to be examined.

4.2.16 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

4.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on craft where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

4.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

4.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

4.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the craft in sheltered waters; the in-water visibility and the cleanliness of the hull below the waterline is to be clear enough to permit a meaningful examination which allows the Surveyor and diver to determine the condition of the plating, appendages and the welding. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

4.3.6 Diving and In-water Survey operations are to be carried out by firms recognised by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

4.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the craft be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.8 Where a vessel has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

4.3.9 Some National Administrations may have requirements additional to those of 4.3.1 to 4.3.8.

■ *Section 5*
Special Survey – General – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of Section 2 are to be complied with so far as applicable.

5.1.3 A Docking Survey in accordance with the requirements of 4.2 is to be carried out as part of the Special Survey.

5.1.4 For vessels assigned the notation 'laid-up', an Underwater Examination (UWE) and general examination of hull and machinery is to be carried out in lieu of the normal Special Survey requirements.

5.2 Preparation

5.2.1 The craft is to be prepared for survey in accordance with the requirements of Table 3.5.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

5.2.2 Where, in accordance with Table 3.5.1, the craft is opened out by removal of linings, ceilings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

Table 3.5.1 Survey preparation

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) and subsequent special surveys
(1) The interior of the craft is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure, *see* 1.5.3. A record is to be made of those areas where lining, ceiling/cabin sole etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of ceiling/cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel craft, *see* Table 3.5.2).	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel craft: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows.

Table 3.5.2 Tank internal examination requirements for steel craft

Tank	Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old)	Special Survey IV (Craft 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES
1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 5.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

5.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

5.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, casings and superstructures are to be examined.

5.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 5.4.4.

5.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

5.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 3.5.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

5.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

5.3.9 Representative structural fastenings, e.g. bolts in way of resiliently mounted deckhouses, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.10 For craft to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

5.4 Examination and testing – Additional items for steel craft

5.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 3.5.2.

5.4.2 In salt water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

5.4.3 The protection of steelwork, other than as referred to in 5.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating. *See also* 1.2.1.

5.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

5.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 6.

5.5 Examination and testing – Additional items for aluminium alloy craft

5.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

5.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

5.6 Examination and testing – Additional items for composite craft

5.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

5.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, etc. is to be examined.

Section 6
Special Survey – Thickness measurement requirements for steel craft

6.1 General

6.1.1 Thickness measurements, as required by Section 5 are to be carried out in accordance with the following requirements.

6.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

6.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR Approval for Thickness Measurement of Hull Structures or by the Surveyor.

6.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements.

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.
(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

6.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

6.1.6 The minimum requirements for thickness measurement are indicated in Table 3.6.1.

6.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 3.6.1 Thickness measurement of steel craft

Special Survey I (Craft 5 years old)	Special Survey II (Craft 10 years old)	Special Survey III (Craft 15 years old) (Craft 20 years old and over)	Special Survey IV and subsequent
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 5.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

6.2 Thickness measurement reporting

6.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

6.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 7* Machinery surveys – General requirements

7.1 Annual, Intermediate and Docking Surveys

7.1.1 For Annual, Intermediate and Docking Surveys, *see* Sections 2, 3 and 4.

7.1.2 For craft where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

7.1.3 For vessels assigned the notation 'laid-up', a general examination of the machinery is to be carried out in lieu of the normal Annual Survey/Intermediate Survey requirements.

7.2 Complete Surveys

7.2.1 While the craft is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 Athwartships thrust propellers are to be generally examined so far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

7.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 11), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

7.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

7.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.8 Fuel tanks which do not form part of the craft's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

7.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 8, 9 and 10 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

Section 8 Gas turbines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 9.1.3).
- All safety devices and local controls.
- Mountings and support frame.

8.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

8.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

Section 9 Oil engines – Detailed requirements

9.1 Complete Surveys

9.1.1 The requirements of Section 7 are to be complied with. *See* 7.2.10 regarding any deviation from the following.

9.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings.
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

9.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

9.1.4 The electric ignition system, if fitted, is to be examined and tested.

9.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

Section 10 Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The requirements of 2.2.14 and 3.2.4 are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 10.2.1.

10.2.5 The generator prime movers are to be surveyed as required by Sections 8 and 9 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

10.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.10 Where the craft is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 10.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation arrangements, is to be examined.

■ *Section 11* Screwshafts, tube shafts, propellers and water jet units

11.1 Frequency of surveys

11.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

11.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

11.1.4 All other shafts not covered by 11.1.1 to 11.1.3 are to be surveyed at intervals of $2^{1}/_{2}$ years.

11.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

11.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

11.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

11.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 7.2.2.

11.2 Normal surveys

11.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 11.1.1 to 11.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

11.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

11.2.3 Water Jet Units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

11.3 Screwshaft Condition Monitoring (SCM)

11.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be entered in column 6 of the *Register Book*:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
- water content
- chloride content
- bearing material and metal particles content
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.
(c) Oil consumption is to be recorded.
(d) Bearing temperatures are to be recorded (two temperature sensors or other approved arrangements are to be provided).
(e) Facilities are to be provided for measurement of bearing weardown.
(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

11.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings, are to be retained on board and audited annually.

11.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 11.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 11.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 11.2.1.

11.4 Modified Survey

11.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 11.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 11.1.2 and 11.1.3.

11.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Wear down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

11.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

11.4.4 Where the descriptive note **SCM** has been assigned as described in 11.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

11.5 Partial Survey

11.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

11.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

11.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 12* **Classification of craft not built under survey**

12.1 General

12.1.1 When classification is desired for a craft not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such craft, when classed, are subsequently to be held as in the case of craft built under survey.

12.1.3 Where classification is desired for a craft which is classed by another recognised Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual craft together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the craft.

12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite craft will be specially considered.

12.2.3 The full requirements of Sections 5 and 6 are to be carried out as applicable. Craft of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel craft, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For craft to which Pt 15, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1 m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new craft and craft which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for craft constructed under Special Survey. For older craft the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the *Rules and Regulations for the Classification of Ships*.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

Periodical Survey Regulations for Yachts

Section

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in Ch 2,4.5. Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Intermediate Surveys as required by Ch 2,4.5.5.
(b) Docking Surveys as required by Ch 2,4.5.6 and 4.5.7.
(c) Special Surveys at five-yearly intervals, *see* Ch 2,4.5.11. For alternative arrangements, *see also* Ch 2,4.5.12, 4.5.13 and 4.5.15.
(d) Complete Surveys of machinery at five-yearly intervals, *see* Ch 2,4.5.16. For alternative arrangements, *see also* Ch 2,4.5.17, 4.5.19, 4.5.21, 4.5.22 and 4.5.23.

1.1.2 When it has been agreed that the Complete Survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed five years, *see* Ch 2,4.5.15 and 4.5.19.

1.1.3 For the frequency of surveys of screwshafts, tube shafts, propellers and water jet units, *see* Section 10.

1.2 Surveys for damage or alterations

1.2.1 At any time when a yacht is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reason, the hull structure in way is to be carefully examined by the Surveyor, or when cement in the bottom or sheathing on decks is removed the structure in way is to be examined before the cement or sheathing is relaid.

1.3 Unscheduled surveys

1.3.1 In the event that Lloyd's Register (hereinafter referred to as 'LR') has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.3.2 In the event of significant damage or defect affecting any yacht, LR reserves the right to perform unscheduled surveys of the hull or machinery of other similar yachts classed by LR and deemed to be vulnerable.

1.4 Surveys for the issue of Convention certificates

1.4.1 Surveys are to be held by LR when so appointed, or by the Exclusive Surveyors to a National Administration or by an IACS Member when so authorised by the National Authority, or, in the case of Cargo Ship Safety Radio Certificates or Safety Management Certificates, by any organisation authorised by the National Authority. In the case of dual classed yachts, Convention Certificates may be issued by the other Society with which the yacht is classed provided this is recognised in a formal Dual Class Agreement with LR and provided the other Society is also authorised by the National Authority.

1.5 Definitions

1.5.1 A **Ballast tank** is a tank which is used primarily for salt water ballast.

1.5.2 **Spaces** are separate hull compartments including integral tanks.

1.5.3 **Suspect areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of substantial corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.
(d) For wood hulls, areas subject to decay as a result of fresh water ingress or poor ventilation.
(e) For high speed craft (as defined in Ch 2,2.2.7), areas of the bottom structure forward prone to slamming damage.
(f) For sailing craft, areas subject to high local stresses due to rigging loads and ballast keel attachments.

1.5.4 **Substantial corrosion** is wastage of individual steel or aluminium plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.5 **Protective coatings** for steel craft should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

1.5.6 **Coating condition** for steel yacht is defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

Section 2
Intermediate Surveys – Hull and machinery requirements

2.1 General

2.1.1 At Intermediate Surveys, the Surveyor is to examine the hull and machinery, so far as necessary and practicable, in order to be satisfied as to their general condition.

2.2 Intermediate Surveys

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of hatchways on freeboard and superstructure decks, weather deck plating, ventilator coamings and air pipes, exposed casings, skylights, flush deck scuttles, deckhouses and companionways, superstructure bulkheads, side, bow and stern doors, windows and storm shutters, side scuttles and deadlights, chutes and other openings, together with all closing appliances and flame screens.

(b) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks; freeing ports, gangways and life-lines.

(c) The efficient condition of bilge level detection and alarm systems on yachts assigned a **UMS** notation.

2.2.2 The anchoring and mooring equipment including anchor warps or wire ropes is to be examined so far as is practicable. For all yachts over 10 years of age the anchors are to be partially lowered and raised using the windlass.

2.2.3 The watertight doors in watertight bulkheads are to be examined and operationally tested locally and where applicable remotely. Other watertight bulkhead penetrations, are to be examined so far as is practicable.

2.2.4 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.2.5 The Surveyor is to generally inspect the machinery spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Where applicable, emergency escape routes are to be checked to ensure that they are free of obstruction.

2.2.6 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.2.7 The bilge pumping systems and bilge wells, including operation of extended spindles, self closing drain cocks and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps, including any hand pumps, is to be proven.

2.2.8 Any pressure vessels including safety devices, foundations, controls, relieving gear, associated piping systems, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.2.9 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions so far as is practicable. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.2.10 The electrical generating sets are to be examined under working conditions.

2.2.11 For yachts having **UMS** or **CCS** notation, a General Examination of automation equipment is to be carried out. Satisfactory operation of safety devices and control systems is to be verified.

2.2.12 For yachts to which Pt 17, Ch 1 applies, the arrangements for fire protection, detection and extinction are to be examined and are to include the following items, as required to be fitted in accordance with the Rules:

(a) Verification, so far as is practicable, that no significant changes have been made to the arrangement of structural fire protection.

(b) Verification of the operation of manual and/or automatic doors where fitted.

(c) Verification that fire control plans are properly posted.

(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).

(e) Examination of fire main system, and confirmation that each fire pump, including the emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.

(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.

(g) Examination of fixed fire-fighting systems controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(j) Verification, so far as is practicable, that the remote control for stopping fans and machinery and shutting off fuel supplies in machinery spaces and, where fitted, the remote controls for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(k) Examination of the closing arrangements of ventilators, skylights and doorways where applicable.
(l) Verification that the fireman's outfits are complete and in good condition.
(m) Verification that gas installations for domestic purposes comply with the relevant statutory requirements.

2.2.13 For steel yachts a general examination of salt-water ballast tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in 1.5.6. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.
(a) For all yachts over five years of age and up to 10 years of age, representative salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in 1.5.6, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel yachts over 10 years of age all salt water ballast tanks, integral sanitary tanks and bilges are to be generally examined.

2.2.14 Representative internal spaces including fore and aft peak spaces, machinery spaces, bilges, etc are to be generally examined. These spaces should include all suspect areas, *see* 1.5.3.

2.2.15 In sailing and auxiliary yachts, the mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined so far as is practicable.

■ *Section 3*
Docking Surveys and In-water Surveys – Hull and machinery requirements

3.1 General

3.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the yacht and machinery, so far as necessary and practicable, in order to be satisfied as to the general condition.

3.2 Docking Surveys

3.2.1 Where a yacht is in dry-dock or on a slipway it is to be placed on blocks of sufficient height and proper staging is to be erected as may be necessary, for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

3.2.2 Attention is to be given to parts of the external hull structure particularly liable to structural deterioration from causes such as high stresses, chafing and lying on the ground, and to areas of structural discontinuity.

3.2.3 The following parts of the external hull structure are to be specially examined:
(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering or other damage which may impair the efficiency of the protection to the underlying laminate.
(d) For wood hulls the condition of any caulking or sheathing is to be examined as applicable. The condition of external fastenings may require to be confirmed by removal at the discretion of the Surveyor.
(e) For sailing or auxiliary yachts fitted with external ballast, the attachment of bilge or centreline ballast keels is to be examined.

3.2.4 Where required by the Rules, the satisfactory condition of the cathodic protection is to be confirmed.

3.2.5 The clearances in the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor rudders are to be lifted for examination of the stock. The securing of rudder couplings and/or pintle fastenings is to be confirmed.

3.2.6 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined.

3.2.7 The propeller and fastenings are to be examined. The sternbush is to be examined as far as is practicable.

3.2.8 The clearance in the sternbush or the efficiency of the oil gland is to be ascertained. The clearance of any shaft bracket bearings is to be ascertained.

3.2.9 The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed.

3.2.10 Special attention is to be given to the hull in way of underwater fittings such as transverse thrusters, stabilisers, etc.

3.2.11 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi hull craft.

3.2.12 Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as is practicable.

3.2.13 Where transom mounted propulsion units are fitted, the steering arrangements and any flexible transom seals are to be examined.

3.2.14 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also* 4.3.7 and Table 4.4.1.

3.3 In-water Surveys

3.3.1 The Committee will accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where an ***IWS** notation is assigned, *see* Ch 2,3.8.2.

3.3.2 The Committee may accept an In-water Survey in lieu of the intermediate docking between Special Surveys required in a five year period on yachts where suitable protection is applied to the underwater portion of the hull. If requested, an ***IWS** class notation may be assigned on satisfactory completion of the Survey, provided that the applicable requirements of the Rules are complied with, *see also* Ch 2,3.8.2.

3.3.3 The In-water Survey is to provide the information normally obtained from the Docking Survey, so far as is practicable.

3.3.4 Proposals for In-water Surveys are to be submitted in advance of the survey being required so that satisfactory arrangements can be agreed with LR.

3.3.5 The In-water Survey is to be carried out at agreed geographical locations under the surveillance of a Surveyor to LR, with the yacht in sheltered waters; the in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory. There is to be good two-way communication between the Surveyor and the diver.

3.3.6 Diving and In-water Survey operations are to be carried out by firms recognised by the Committee. Continued recognition by the Committee will be dependent on the standard of workmanship by the firm being maintained to the satisfaction of LR's Surveyors.

3.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may require that the yacht be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

3.3.8 Where a yacht has an ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry-docking in order that the ***IWS** notation can be maintained.

3.3.9 Some National Administrations may have requirements additional to those of 3.3.1 to 3.3.8.

■ *Section 4* Special Survey – General – Hull requirements

4.1 General

4.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

4.1.2 The requirements of Section 2 are to be complied with so far as applicable.

4.1.3 A Docking Survey in accordance with the requirements of 3.2 is to be carried out as part of the Special Survey.

4.1.4 For sailing and auxiliary yachts fitted with unclassed machinery installations the requirements of 11.3.1 are to be complied with.

4.2 Preparation

4.2.1 The yacht is to be prepared for survey in accordance with the requirements of Table 4.4.1. The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

4.2.2 Where, in accordance with Table 4.4.1, the yacht is opened out by removal of linings, cabin sole, etc., and defects are found, further opening out will be required in order that the Surveyor can confirm the full extent of the defects.

4.3 Examination and testing – General

4.3.1 All spaces within the hull and superstructure including integral tanks are to be examined (*see also* 4.4.1 for tank examinations on steel craft). Special attention is to be paid to any suspect areas, *see* 1.5.3.

Table 4.4.1 Survey preparation

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old) and subsequent special surveys
(1) The interior of the yacht is to be sufficiently opened out by the removal of lining, ceiling/cabin sole, portable tanks and ballast, etc as required in order that the Surveyor may be satisfied as to the condition of suspect areas of the structure (*see* 1.5.3). A record is to be made of those areas where lining, cabin sole, etc., were opened out and where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys. (2) Machinery compartments, fore and aft peaks and other spaces as directed by the Surveyor, are to be cleared and cleaned as necessary, and the bilges and limbers all fore and aft are to be cleaned and prepared for examination. Platform plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure. (3) In way of the single and/or double bottom areas, a sufficient amount of cabin sole is to be lifted to permit examination of the bilges and/or tanktops below. (4) All integral tanks are to be cleaned as necessary to permit examination. (For steel yachts, *see* Table 4.4.2). (5) In sailing and auxiliary yachts the sails are to be laid out so that they can be properly examined.	In addition to the requirements for Special Survey I, the following are to be complied with: (1) The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables/anchor warps, as applicable, are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection. (2) The rudder is to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor. For sailing or auxiliary yachts: (3) On yachts fitted with an external ballast keel, fastenings are to be drawn for examination as may be required by the Surveyor. (4) On yachts fitted with a centreplate or lifting keel, the pivot bolts and lifting arrangements are to be dismantled for examination as required by the Surveyor. For wood yachts: (5) Where the hull is sheathed with metal, such sheathing as will permit an examination of the stem, wood keel, garboards, plank ends and sternpost is to be removed as required by the Surveyor. (6) Fastenings are to be drawn as may be required by the Surveyor. (7) The outside surface of the planking is to be scraped bright at the discretion of the Surveyor.	In addition to the requirements for Special Survey II the following are to be complied with: (1) Linings, ceiling/cabin soles, etc. are to be removed as required in order that the Surveyor may be satisfied as to the condition of the structure. For steel yachts: (2) Portions of wood sheathing, or other covering, on steel decks are to be removed, as considered necessary by the Surveyor, in order to ascertain the condition of the plating. (3) Where spaces are insulated, sufficient insulation is to be removed in each space to enable the Surveyors to be satisfied with the condition of the structure. (4) Linings are to be removed in way of shell plating immediately above tank top connections to the side shell, in way of galleys/washrooms and beneath portlights and windows. For sailing or auxiliary yachts: (5) The masts are to be unshipped for survey. The whole of the standing rigging, including rigging screws, bolts, pins and fittings, is to be dismantled as considered necessary by the Surveyor. NOTE This requirement may be waived at alternate Special Surveys provided the masts and rigging are thoroughly examined *in situ*. (6) On yachts fitted with an external ballast keel, a minimum of 50% of the total number of ballast keel fastenings are to be drawn for examination as required by the Surveyor. If defects are found the remaining fastenings should be drawn for sexamination. For wood yachts: (7) Where iron or mild steel fastenings are used, as a minimum requirement the following are to be drawn for examination where applicable: • 6 floor arm fastenings each side. • 4 hanging knee fastenings each side. • 4 chain plate fastenings each side at each mast. • 18 frame to plank fastenings each side. • 12 garboard and 12 plank end fastenings each side.

4.3.2 Double bottom compartments, peak tanks and all other integral tanks are to be tested by a head sufficient to give the maximum pressure that can be experienced in service. Tanks may be tested afloat provided that their internal examination is also carried out afloat.

4.3.3 Where repairs are effected to the hull shell or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

4.3.4 All decks, casings and superstructures are to be examined.

4.3.5 The satisfactory attachment of any wood or other deck sheathing is to be confirmed, *see also* 4.4.4.

4.3.6 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

4.3.7 The anchors are to be examined. If the chain cables are ranged they are to be examined together with the chain locker, *see* Table 4.4.1. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. The windlass is to be examined.

4.3.8 The Surveyor is to be satisfied that there are suitable towlines and mooring ropes when these are a Rule requirement.

4.3.9 Representative structural fastenings, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

4.3.10 For yachts to which Pt 17, Ch 1 applies, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew and passenger spaces, and spaces in which crew are normally employed.

4.4 Examination and testing – Additional items for steel yachts

4.4.1 All integral tanks are generally to be internally examined. However, in certain circumstances the internal examination of lubricating oil, fresh water and oil fuel tanks may be waived. For the minimum extent of tank internal examination, *see* Table 4.4.2.

4.4.2 In salt water ballast spaces, integral sanitary tanks and bilges, where the protective coating is found to be other than in GOOD condition as defined in 1.5.6 and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged as necessary annually.

4.4.3 The protection of steelwork, other than as referred to in 4.4.2 should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

4.4.4 Wood decks or sheathing are to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. When a wood deck, laid on stringers and ties, has worn by 20 per cent or more in thickness, it is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also* 1.2.1.

4.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deckhouses is to be examined.

Table 4.4.2 Tank internal examination requirements for steel yachts

Tank	Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV (Yachts 20 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	*See* Note 2	*See* Note 3	All tanks
Fresh water	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Oil fuel	None	*See* Note 1	*See* Note 2	*See* Note 3	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

NOTES

1. Tanks (excluding peak tanks) used exclusively for oil fuel or fresh water need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of the after end of one forward double bottom tank, and of one selected deep tank.
2. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from an internal examination of one double bottom tank forward and one aft and one deep tank.
3. Tanks (excluding peak tanks) used exclusively for oil fuel, oil fuel and fresh water ballast, or lubricating oil, need not all be examined internally provided that the Surveyor is satisfied with the condition, after both external examination and testing and from internal examination of a least one double bottom tank amidships, one forward and one aft and one deep tank.
4. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement is fitted under sounding pipes. In the case of tanks fitted only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

4.4.6 The Surveyors may require to measure the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. The minimum requirements for thickness measurements are given in Section 5.

4.5 Examination and testing – Additional items for aluminium alloy yachts

4.5.1 The structure in way of any bimetallic connections is to be examined and the efficiency of the insulation arrangements confirmed.

4.5.2 The Surveyor may require to measure the thickness of the material in any portion of the structure where signs of deterioration are evident or may normally be found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality.

4.6 Examination and testing – Additional items for composite yachts

4.6.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

4.6.2 The hull to deck joint together with any joints between the deck and deckhouses or superstructures are to be examined.

4.6.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, windlass, shaft brackets, fendering, mooring bitts, mast steps, rigging chainplates, etc., is to be examined.

4.7 Examination and testing – Additional items for wood yachts

4.7.1 Where hulls are provided with metal sheathing, the condition of the structure in way of any sheathing is to be confirmed. For the extent of removal of metal sheathing *see* Table 4.4.1. The satisfactory adhesion of any glass/nylon reinforced plastic sheathing is also to be confirmed.

4.7.2 Wood decks or sheathing are to be examined and the caulking is to be tested and re-caulked as necessary. If decay or rot is found or the wood has worn by 20 per cent or more in thickness, the wood is to be renewed. Attention is to be given to the condition of the structure under wood decks, and to fabric deck coverings. If it is found that such coverings are damaged or are not adhering closely to the deck, sections are to be removed as necessary to ascertain the condition of the deck under.

4.7.3 Fastenings as may be required by the Surveyor are to be drawn for examination, *see* Table 4.4.1.

4.8 Examination and testing – Additional items for sailing and auxiliary yachts

4.8.1 The mast(s), mast steps, spars, standing and running rigging, rigging screws, chainplates and sails are to be examined, *see* Table 4.4.1.

4.8.2 The structure in way of the attachment of bilge or centreline ballast keels is to be examined. Ballast keel bolts are to be tested to ascertain their soundness and may require to be drawn for examination, *see* Table 4.4.1.

4.8.3 On yachts fitted with a centreplate or lifting keel, the pivot bolt and lifting arrangements are to be examined as far as is practicable.

■ *Section 5*
Special Survey – Thickness measurement requirements for steel yachts

5.1 General

5.1.1 Thickness measurements, as required by Section 4 are to be carried out in accordance with the following requirements.

5.1.2 Thickness measurements are to be taken at the forward and aft areas of all plates. In all cases the measurements are to represent the average of the multiple measurements taken on each plate. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are renewed, the thicknesses of adjacent plates in the same strake are to be reported.

5.1.3 Thickness measurements are normally to be by means of ultrasonic test equipment and are to be carried out by a firm qualified as Grade 1 or Grade 2 according to LR's *Approval for Thickness Measurement of Hull Structures* or by the Surveyor.

5.1.4 The degree of supervision or check testing by the Surveyor is dependent upon the grade of approval extended to the firm carrying out the thickness measurements:

(a) The work of firms having Grade 1 approval is subject to check testing by the Surveyor.
(b) Thickness measurements by firms having Grade 2 approval is to be carried out with the Surveyor substantially in attendance.

5.1.5 Thickness measurements may be carried out in association with the fourth Annual Survey.

5.1.6 The minimum requirements for thickness measurement are indicated in Table 4.5.1.

5.1.7 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 4.5.1 Thickness measurement of steel yachts

Special Survey I (Yachts 5 years old)	Special Survey II (Yachts 10 years old)	Special Survey III (Yachts 15 years old)	Special Survey IV and subsequent (Yachts 20 years old and over)
Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) Any exposed plating throughout the Main Deck. (2) Shell plating in way of the waterline throughout the length of the craft. (3) Suspect areas, as required by the Surveyor may include areas where the coatings are found to be other than in GOOD condition, *see* Note 1.	(1) All Main Deck plating outside deckhouses or superstructures and including plating in way of wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the craft. (3) 2 transverse sections of deck and shell plating within 0,5*L* amidships. (4) Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Shell and tanktop plating immediately adjacent to tank top margins. (c) Bottom shell in way of any cement, asphalt or other composition. (d) Shell plating below portlights and windows. (e) Tanktop plating below ceiling or cabin soles. (f) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces. (g) Structure in way of integral sanitary tanks.

NOTES
1. Suspect areas are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include, for steel hulls, areas of substantial corrosion and/or fatigue cracking, *see also* 1.5.3 and 4.4.6.
2. Coating condition for steel craft is defined in 1.5.6.

5.2 Thickness measurement reporting

5.2.1 A report is to be prepared by the approved firm carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator and supervisor.

5.2.2 The thickness measurement report is to be verified and signed by the Surveyor.

■ *Section 6*
Machinery surveys – General requirements

6.1 Intermediate and Docking Surveys

6.1.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

6.1.2 For yachts where an Approved Planned Maintenance Scheme is in operation an Annual Survey of the machinery is to be carried out together with an audit of the maintenance and monitoring records.

6.2 Complete Surveys

6.2.1 While the yacht is in dry-dock, all openings to the sea in the machinery spaces and pump-rooms, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined. For athwartships thrust propellers, *see* 10.1.8.

6.2.2 Athwartships thrust propellers are to be generally examined as far as is possible in dry dock and tested under working conditions afloat for satisfactory operation.

6.2.3 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in Section 10), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

6.2.4 An examination is to be made as far as practicable of all propulsion gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated clutch arrangements.

6.2.5 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for essential services.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks or resilient mounts of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.

6.2.6 All air receivers for essential services, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

6.2.7 The valves, cocks and strainers of the bilge system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The oil fuel, feed, lubricating oil and cooling water systems also any ballast connections together with all pressure filters, heaters and coolers used for essential services, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

6.2.8 Fuel tanks which do not form part of the yacht's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all oil fuel tanks are to be examined, so far as is practicable.

6.2.9 Where remote and/or automatic controls are fitted for essential machinery, they are to be tested to demonstrate that they are in good working order.

6.2.10 In addition to the above, detailed requirements for gas turbines and oil engines and electrical installations are given in Sections 7, 8 and 9 respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, the Committee will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records, *see* Ch 2,4.5.17 and 4.5.23.

■ *Section 7*
Gas turbines – Detailed requirements

7.1 Complete Surveys

7.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

7.1.2 The following parts are to be opened out and examined:

- Compressor including impellers or blading, rotors and casing.
- Combustion chambers, burners, intercoolers and heat exchangers.
- Gas, air and fuel piping and fittings.
- Gas generator turbine and power turbine blading, rotors and casing.
- Rotors to include couplings, clutches, bearings and tie bolts.
- Auxiliary mounted fuel, L.O. and cooling water pumps, their drive transmissions and fittings.
- Starting system (for starting air pipes, *see* 8.1.3).
- All safety devices and local controls.
- Mountings and support frame.

7.1.3 The compressor/turbine units are to be operated and maintained in accordance with the manufacturer's instructions. Overhauls, including the prescribed replacement of limited life components, are to be undertaken at the specified intervals. Full service records are to be available for review by the Surveyor.

7.1.4 The manoeuvring of the propulsion system is to be tested under working conditions.

■ *Section 8*
Oil engines – Detailed requirements

8.1 Complete Surveys

8.1.1 The requirements of Section 6 are to be complied with. *See* 6.2.10 regarding any deviation from the following.

8.1.2 The following parts are to be opened out and examined:

- Cylinders and covers.
- Valves and valve gear.
- Pistons and connecting rods.
- Crankshafts and all bearings
- Crankcases and entablatures.
- Crankcase door fastenings and explosion relief devices.
- Turbo-chargers and their associated coolers.
- Air compressors and their intercoolers.
- Filters and/or separators and safety devices.
- Fuel pumps and fittings.
- Camshaft drives and balancer units.
- Vibration dampers or detuners.
- Flexible couplings and clutches.
- Reverse gears.
- Attached pumps and cooling arrangements.

8.1.3 Selected pipes in the starting air system, if fitted, are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors.

8.1.4 The electric ignition system, if fitted, is to be examined and tested.

8.1.5 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

■ *Section 9*
Electrical equipment

9.1 Intermediate Surveys

9.1.1 The requirements of 2.2.9 and 2.2.13 are to be complied with as far as applicable.

9.2 Complete Surveys

9.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided or equipment, which may be damaged, disconnected for the purpose of this test.

9.2.2 The fittings on the main and emergency switch-boards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

9.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

9.2.4 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by 9.2.1.

9.2.5 The generator prime movers are to be surveyed as required by Sections 7 and 8 and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

9.2.6 Where transformers or electrical apparatus associated with supplies to essential services are liquid filled or cooled by a liquid in direct contact with current carrying parts, the owner is to arrange for samples of the liquid to be taken and tested, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be furnished to the Surveyor.

9.2.7 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

9.2.8 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

9.2.9 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

9.2.10 Where the yacht is electrically propelled, the propulsion motors, generators, cables and all ancillary electrical gear, exciters and ventilating plant (including coolers) associated therewith are to be examined, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and slip-rings. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Liquids for filling and cooling, if used, are to be tested in accordance with 9.2.6. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

9.2.11 Where batteries provide the source of power for any essential services, their installation, including charging and ventilation, is to be examined.

Section 10 Screwshafts, tube shafts, propellers and water jet units

10.1 Frequency of surveys

10.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of five years when the keyway complies fully with the present Rules.

10.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of five years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

10.1.4 All other shafts not covered by 10.1.1 to 10.1.3 are to be surveyed at intervals of $2^{1}/_{2}$ years.

10.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

10.1.6 Directional propeller units for main propulsion purposes are to be surveyed at intervals not exceeding five years.

10.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding five years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

10.1.8 Athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding five years, *see* 6.2.2.

10.2 Normal surveys

10.2.1 All screwshafts are to be withdrawn for examination by LR's Surveyors at the intervals prescribed in 10.1.1 to 10.1.4. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the control gear.

10.2.2 Directional propeller units are to be dismantled for examination of the propellers, shafts, gearing and control gear.

10.2.3 Water jet units are to be dismantled for examination of the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlets channels, steering nozzle, reversing arrangements, and control gear.

10.3 Screwshaft Condition Monitoring (SCM)

10.3.1 Where oil lubricated shafts with approved oil glands are fitted, and the Owner has complied with the following requirements, the descriptive note **SCM** (Screwshaft Condition Monitoring) may be assigned:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. The lubricating oil analysis documentation is to be available on board. Each analysis is to include the following minimum parameters:
- water content
- chloride content
- bearing material and metal particles content
- oil ageing (resistance to oxidation).

(b) Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(c) Oil consumption is to be recorded.

(d) Bearing temperatures are to be recorded, (two temperature sensors or other approved arrangements are to be provided).

(e) Facilities are to be provided for measurement of bearing weardown.

(f) Oil glands are to be capable of being replaced without withdrawal of the screwshaft.

10.3.2 For maintenance of the descriptive note **SCM**, the records of analyses, consumption and temperatures, together with weardown readings are to be retained on board and audited annually.

10.3.3 Where the requirements for the descriptive note **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by 10.2.1 provided all condition monitoring data is found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method. The remaining requirements of 10.2.1 are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction the shaft will be required to be withdrawn in accordance with 10.2.1.

10.4 Modified Survey

10.4.1 A Modified Survey may be accepted at alternate five-yearly surveys for shafts described in 10.1.1 provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in 10.1.2 and 10.1.3.

10.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible.

Wear-down is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the control gear.

10.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

10.4.4 Where the descriptive note **SCM** has been assigned as described in 10.3.1 and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

10.5 Partial Survey

10.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, the Committee will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

10.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

10.5.3 The Committee will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 11*
Surveys of unclassed machinery in existing classed yachts

11.1 General

11.1.1 The requirements of this survey are considered necessary in order to establish, so far as practicable, that the unclassed machinery installation does not constitute a hazard to the classed hull. The survey is applicable only to existing sailing yachts fitted with unclassed auxiliary propulsion engines not exceeding 37 kW.

11.1.2 At any time when unclassed machinery in an existing classed yacht is undergoing alteration and/or replacement, the requirements of Ch 2,4.4.6 are to be complied with.

11.2 Intermediate and Docking Surveys

11.2.1 For Intermediate and Docking Surveys, *see* Sections 2 and 3.

11.3 Complete Surveys

11.3.1 At each Special Survey of the hull the requirements of 11.2.1 and the following are to be complied with:

(a) The bilge pumping system is to be examined and tested under working conditions.
(b) A general examination is to be made of the fuel tanks and fuel system with their valves, pipes and fittings, and of the engine exhaust system, piping and fittings.
(c) A general examination of the electrical equipment is to be made and, if considered necessary, a test of the insulation resistance is to be carried out in accordance with 9.2.1.
(d) The starting arrangements are to be examined.
(e) The screwshafts and tube shafts are to be withdrawn for examination.
(f) The main and essential auxiliary machinery is to be examined under full working conditions in accordance with 8.1.4.

■ *Section 12*
Classification of yachts not built under survey

12.1 General

12.1.1 When classification is desired for a yacht not built under the supervision of LR's Surveyors, application should be made to the Committee in writing.

12.1.2 Periodical Surveys of such yachts, when classed, are subsequently to be held as in the case of yachts built under survey.

12.1.3 Where classification is desired for a yacht which is classed by another recognised Society, special consideration will be given to the scope of the survey.

12.2 Hull and equipment

12.2.1 Plans showing the main scantlings and arrangements of the actual yacht together with any proposed alterations are to be submitted for approval.These should comprise plans of the midship section, longitudinal section and decks, and such other plans as may be requested. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the yacht.

12.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite yachts will be specially considered.

12.2.3 The full requirements of Sections 4 and 5 are to be carried out as applicable. Yachts of recent construction will receive special consideration.

12.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of steel yachts, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted. For yachts to which Pt 17, Ch 1 applies, fire protection, detection and extinction are to be in accordance with the Rules.

12.2.5 When the full survey requirements indicated in 12.2.3 and 12.2.4 cannot be completed at one time, the Committee may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merits of each particular case, which should be submitted for consideration.

12.3 Machinery

12.3.1 To facilitate the survey, the following plans and particulars (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of any boilers, air receivers and important forgings are to be submitted:

- Name of manufacturer of engine and gearbox including the manufacturer's type designation of engine and gearbox, together with the continuous shaft power of the engine at the crankshaft coupling with the revolutions per minute of crankshaft and propeller.
- General pumping arrangements, including air and sounding pipes (Builder's plan).
- Bilge, ballast and oil fuel pumping arrangements including the capacities of the pumps on bilge service.
- Arrangement and dimensions of any steam pipes.
- Arrangement of oil fuel pipes and fittings at settling and service tanks.
- Arrangement of oil fuel piping in connection with oil burning installations.
- Oil fuel overflow systems, where these are fitted.
- Arrangement of boiler feed systems.
- Oil fuel settling, service and other oil fuel tanks not forming part of the craft's structure.
- Boilers and economisers.
- Air receivers.
- Crank, thrust, intermediate and screw shafting.
- Details of water jet or directional propeller units, if fitted.
- Clutch and reversing gear with methods of control.
- Reduction gearing.
- Propeller (including spare propeller if supplied) where the diameter exceeds 1m.
- Electrical circuits.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangement of lubricating oil, other flammable liquids and cooling water systems for main and auxiliary services.
- Steering gear including control arrangement.
- Arrangement of exhaust system indicating materials, method of cooling, and if water spray injected, the method of draining.

12.3.2 Plans additional to those detailed in 12.3.1 are not to be submitted unless the machinery is of a novel or special character affecting classification.

12.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

12.3.4 For new yachts and yachts which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for yachts constructed under Special Survey. For older yachts the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, the Committee may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

12.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

12.3.6 The screwshaft is to be drawn and examined.

12.3.7 Any steam pipes or oil burning installations are to be examined and tested as required by Pt 1, Ch 3,15 or Ch 3,16 of the *Rules and Regulations for the Classification of Ships*.

12.3.8 The bilge, ballast and oil fuel pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

12.3.9 The electrical equipment is to be examined as required at Complete Surveys.

12.3.10 The whole of the machinery, including essential controls, is to be tried under working conditions to the Surveyor's satisfaction.

Periodical Survey Regulations for Amphibious Air Cushion Vehicles (ACV)

■ *Section 1* General

1.1 Frequency of surveys

1.1.1 Except as amended at the discretion of the Committee, the periods between surveys are as follows:

(a) Annual Surveys are to be held within three months before or after each anniversary of the completion, commissioning or Special Survey.
(b) Intermediate Surveys are to be held instead of the second or third Annual Survey after completion, commissioning or Special Survey.
(c) Special Surveys (hull and machinery) are to be held at the fifth anniversary after completion, commissioning or previous Special Survey.

1.2 Machinery surveys

1.2.1 The manufacturer's approved operating and service instructions for the main and auxiliary power units, transmission systems, propellers and lift fans are to be incorporated into an approved planned maintenance scheme for the ACV.

1.2.2 Maintenance, overhaul or replacement will then normally be determined by the specified condition/ performance monitoring limits and running hours.

1.2.3 It is a requirement of this arrangement that any significant defect, damage repair or alteration be reported to Lloyd's Register (hereinafter referred to 'LR') without delay, *see also* Ch 2,1.1.7.

1.3 Surveys for damage, repairs or alterations

1.3.1 At any time when an ACV is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult to access are to be specially examined, e.g. if any part of the main or auxiliary machinery is removed for any reasons, the hull structure in way is to be carefully examined by the Surveyor.

1.3.2 All significant repairs, alterations, approved modifications and replacements are to be recorded in the ACV's Log Books in a manner that will enable their later identification by the Surveyors, *see also* Ch 2,4.4.1 and 4.4.6.

1.3.3 Trials are to be made on any craft which have been significantly modified, overhauled or repaired, prior to returning to service, to ensure to the Surveyor's satisfaction that the ACV has been returned in a satisfactory condition for its intended service.

1.4 Unscheduled surveys

1.4.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys of the hull or machinery.

1.5 Surveys for the issue of Convention Certificates

1.5.1 Surveys are to be held either by LR when so appointed or by the Exclusive Surveyors of a National Administration when so delegated by a Flag State.

■ *Section 2* Annual Surveys – Hull and machinery requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant statutory annual or other statutory surveys, wherever practicable.

2.1.2 The Surveyor is to audit the approved planned maintenance scheme. The records will be checked and the satisfactory operation of the scheme verified. Condition monitoring data will be reviewed and trends analysed.

2.1.3 The Surveyor is to examine the Log Book to verify that a proper record has been kept in respect of servicing, maintenance and overhaul requirements for those aspects not covered by the approved planned maintenance scheme.

2.1.4 Certification for replacement units/parts will be required.

2.2 Preparation

2.2.1 The ACV is to be slung or jacked up to permit a thorough inspection of all underside parts, fittings and attachments.

2.2.2 Panelling, floor coverings, etc. need not be removed at these surveys, unless they are of portable type or unless the Surveyor has reason to suspect they may conceal significant damage.

2.3 Hull items

2.3.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Bottom and side plating, any external stiffeners, and side walls or skirts, including flexible keels, if any.
(b) Weather doors, ventilators, windows and emergency or other hatches.
(c) Weather decks, houses, etc.
(d) Machinery casings and seats.
(e) Anchoring and mooring equipment when required by the Rules.
(f) Fire equipment including fire detection, alarm systems and means of escape , where the survey of such items is not covered by statutory certification.
(g) Where applicable, passenger seat foundations and cargo tie down points.
(h) Skirt attachment and operating mechanisms.
(j) Air propeller shroud structures.
(k) Side body attachments and supports (when fitted).
(l) Operation of ramps, and their closing and locking arrangements.
(m) The structural attachment and retention arrangements for external fuel tanks (when fitted).

2.4 Machinery items

2.4.1 The Surveyor is to be satisfied as to the efficient condition of the following items:

(a) Fuel tanks and associated fuel system with pumps, filters, etc.
(b) Lubricating oil tanks and associated lubricating system with coolers, pumps, filters, etc.
(c) The bilge pumping system.
(d) Machinery alarm arrangements.
(e) The electrical machinery, the switchgear and other electrical equipment are to be generally examined under operating conditions so far as practicable. The satisfactory operation of the emergency source of power, including the automatic controls as fitted, is to be verified.
(f) Hydraulic, electrical and pneumatic control systems, including steering, are to be examined under operating conditions.
(g) Engine starting arrangements.
(h) All drive belts, associated running surfaces and tension adjustment (where fitted).
(j) Air propellers, including (where fitted) hub assemblies, servos and actuating equipment of controllable pitch propellers.
(k) The overall operation of the machinery including propulsion and lift machinery. A machinery proving trial of short duration is to demonstrate to the Surveyor the satisfactory operation of the machinery.

■ *Section 3*
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 The requirements of Section 2 are to be complied with.

3.2 Preparation

3.2.1 A sufficient amount of panelling, floor covering, insulation and paint etc., is to be removed to enable the Surveyors to satisfy themselves that all major structural items are in a satisfactory condition.

3.3 Examination and testing

3.3.1 Representative integral tanks and buoyancy spaces are to be examined as necessary to ensure that they continue to be in a satisfactory condition.

3.3.2 At the discretion of the Surveyor, tanks or buoyancy spaces may require to be tested to ensure that they continue to be tight.

■ *Section 4*
Special Surveys (Hull and machinery)

4.1 General

4.1.1 The requirements of Sections 2 and 3 are to be complied with.

4.2 Hull Surveys

4.2.1 All integral tanks and buoyancy spaces are to be examined and tested to ensure that they continue to be tight and in a satisfactory condition.

4.2.2 All other hull compartments are to be examined.

4.2.3 The anchoring and mooring equipment, when required by the Rules, is to be examined to ensure its efficiency, accessibility and readiness for use. Anchor cables or warps are to be ranged for examination.

4.3 Machinery Surveys

4.3.1 The main and essential auxiliary machinery is to be generally examined with particular attention given to safety devices, fastening arrangements and resilient mountings. A limited opening up, e.g. removal of inspection covers, should be undertaken in order that the Surveyor can confirm the satisfactory condition of these items.

4.3.2 Where not carried out as a regular monitoring procedure, lubricating oil analysis may be required.

4.3.3 Items that have not been overhauled as part of the approved planned maintenance scheme since installation, commissioning or the previous Special Survey may require to be opened up for examination.

4.3.4 The insulation resistance of the electrical equipment and connections is to be tested.

■ *Section 5*
Classification of ACVs not built under survey

5.1 General

5.1.1 The requirements for classification of an ACV not built under the supervision of LR's Surveyors are to be in accordance with the applicable sub-Sections of Pt 1, Ch 3,12.

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Rules for the Manufacture, Testing and Certification of Materials

July 2012

Lloyd's Register

LIFE MATTERS

A guide to the Rules

and published requirements

Rules for the Manufacture, Testing and Certification of Materials

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Numbering and Cross-References

A decimal notation system has been adopted throughout. Five sets of digits cover the divisions, i.e. Part, Chapter, Section, sub-Section and paragraph. The textual cross-referencing within the text is as follows, although the right hand digits may be added or omitted depending on the degree of precision required:

(a) In same Chapter, e.g. *see* 2.1.3 (i.e. down to paragraph).

(b) In another set of Lloyd's Register Rules, e.g. *see* Pt 5, Ch 3,2.1 of the Rules and Regulations for the Classification of Ships.

The cross-referencing for Figures and Tables is as follows:

(a) In same Chapter, e.g. as shown in Fig. 2.3.5 (i.e. Chapter, Section and Figure Number).

(b) In another set of Lloyd's Register Rules, e.g. *see* Table 2.7.1 in Pt 3, Ch 2 of the Rules and Regulations for the Classification of Special Service Craft.

Rules updating

The Rules are generally published annually and changed through a system of Notices. Subscribers are forwarded copies of such Notices when the Rules change.

Current changes to Rules that appeared in Notices are shown with a black rule alongside the amended paragraph on the left hand side. A solid black rule indicates amendments and a dotted black rule indicates corrigenda.

July 2012

RULES FOR THE MANUFACTURE, TESTING AND CERTIFICATION OF MATERIALS

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■ *Section 1* Scope

1.1 General

1.1.1 Materials used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by Lloyd's Register (hereinafter refered to as LR), are to be manufactured, tested and inspected in accordance with these Rules.

1.1.2 Wrought, cast and extruded materials are to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapters 3 to 9 of these Rules. Mooring and anchoring equipment is to comply with the requirements of Chapters 1 and 2, and the appropriate specific requirements of Chapter 10. Manufacturers of these materials must be approved by LR according to the requirements in Sections 2 or 3. Only those materials within a manufacturer's scope of approval may be used.

1.1.3 Welding consumables are to comply with the requirements of Chapter 11 of these Rules.

1.1.4 Where welding is used for the construction, conversion, modification or repair of ships, other marine structures and associated machinery which are classed or are intended for classification by LR, welding qualifications and tests shall be performed according to Chapter 12 of these Rules. All welding shall be performed according to Chapter 13 of these Rules.

1.1.5 Plastics materials are to comply with the requirements of Chapter 14 of these Rules.

1.1.6 The materials and components which are to comply with these requirements for the purposes of classification are defined in the relevant Rules dealing with design and construction.

■ *Section 2* Approval and survey requirements

2.1 Approval and survey requirements – General

2.1.1 Marine materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be made at works which have been approved by LR for the type and grade of product being supplied.

2.1.2 Materials manufactured in accordance with Chapters 3 to 10 of these Rules are to be manufactured, tested and inspected under Survey according to the requirements of one of the following two schemes:
(a) The Materials Survey Scheme, *see* 2.3.
(b) The Materials Quality Scheme, *see* 2.4.

2.1.3 For the purposes of survey, LR Surveyors are to be allowed access to all relevant parts of the works, and are to be provided with the necessary facilities and information to enable them to verify that the manufacture is being carried out in accordance with the approved procedures. Facilities are also to be provided for the selection of test material, the witnessing of mechanical tests and the examination of materials, as required by these Rules.

2.1.4 Where a production process, testing or examination of materials is sub-contracted, this must be with the approval of LR. Surveyors are to be allowed access to the sub-contractor's premises in order to conduct Surveys according to the requirements of these Rules.

2.1.5 Products manufactured in accordance with Chapters 11 and 14 are to be approved in accordance with the requirements therein. For these materials, approval is given for a specific product on a type approval basis, rather than the approved manufacturer/survey arrangements applied to materials covered by Chapters 3 to 10.

2.2 LR Approval – General

2.2.1 Unless specifically stated in other Chapters of these Rules, all LR approvals apply to materials used in applications intended for marine service, as described in 1.1.

2.2.2 The procedures for application for approval of manufacturers and products, the details of the information to be supplied by the manufacturer, and the test programme to be conducted on the products are given in the appropriate book of LR's *Materials and Qualification Procedures for Ships* (MQPS). This is published in the CD Live section of LR's web site at http://www.lr.org.

2.2.3 LR publishes lists of approved manufacturers and approved products. The lists are published in the CD Live section of LR's website, http://www.lr.org.
The lists are as follows:

- *List of Approved Manufacturers of Materials*.
- *Approved Welding Consumables for Use in Ship Construction*.
- *Lists of Paints, Resins, Reinforcements and Associated Materials*.
- *Lists of Approved Anchors*.

2.2.4 For initial LR approval as an Approved Manufacturer for a particular material, the manufacturer is required to demonstrate to the satisfaction of LR, that the necessary manufacturing and testing facilities are available, and are supervised by suitably qualified personnel. A specified programme of tests is to be carried out under the supervision of LR Surveyors, and the results are to be to the satisfaction of LR.

2.2.5 If the results of the initial assessment of the manufacturer, and the test programme are considered satisfactory, the manufacturer will be added to the list of approved manufacturers of materials, and a certificate of approval will be issued to the manufacturer by LR, showing the scope of materials and grades covered by the approval. Initial approval will generally be under the Materials Survey Scheme, *see* 2.3.

2.2.6 Approved manufacturers who meet the entry requirements, may apply for approval under the Materials Quality Scheme, *see* 2.4.

2.2.7 When a manufacturer has more than one works, the manufacturer's approval shall only be valid for the works where the test programme was conducted.

2.2.8 It is the manufacturer's responsibility to advise LR of all changes to the manufacturing process parameters that may affect the application of the material, prior to the adoption of the changes in production. Additional approval tests may be required to maintain the approval.

2.2.9 Maintenance of approval is dependent on the manufacturer continuing to meet the requirements of the applicable sections of these Rules.

2.2.10 Where it is considered that an approved manufacturer is not maintaining its responsibilities to comply with these Rules, the approval may be suspended by LR until such time that agreed corrective and preventive actions are considered to have been satisfactorily carried out. If considered necessary, LR may require that the normal level of testing and inspection is increased.

2.2.11 In all instances, LR will reduce the scope of, or withdraw approval from, a manufacturer where it becomes apparent that the manufacturer is unable to maintain compliance with these Rules, or the scope of approval.

2.2.12 Where a manufacturer disagrees with any decisions made with regard to LR approval, they may appeal in writing to LR.

2.2.13 Any documents, data or other information received as part of the approval process, will be treated as strictly confidential, and will not be disclosed to any third party, without the manufacturer's prior written consent.

2.3 Materials Survey Scheme

2.3.1 Materials according to Chapters 3 to 10 of these Rules and produced under the Materials Survey Scheme will be subject to Direct Survey by an LR Surveyor. The scheme requires the Surveyor to survey and certify all materials according to the requirements of these Rules.

2.3.2 Approved manufacturers are to request a survey of the material by an LR Surveyor, when required. Manufacturers must provide the Surveyor with details of the order, specification and any special conditions additional to the requirements of these Rules.

2.3.3 All mechanical tests required by these Rules are to be witnessed. The Surveyor may allow part of this task to be carried out by a member of the works staff by prior written agreement.

2.3.4 Before final acceptance, all materials are to be submitted to the specified tests and examinations under conditions acceptable to the Surveyor. The results are to comply with the Rules, and all materials are to be to the satisfaction of the Surveyor.

2.3.5 The specified tests and examinations are to be carried out prior to the despatch of finished materials from the manufacturer's works. Where materials are supplied in the rough or unfinished condition, as many as possible of the specified tests are to be carried out by the manufacturer, and any tests or examinations that are not completed are to be carried out under survey at a subsequent stage of manufacture.

2.3.6 In the event of any material proving unsatisfactory during subsequent working, machining or fabrication, such material is to be rejected, notwithstanding any previous certification.

2.3.7 In addition to witnessing test results, the Surveyor is responsible for ensuring that the manufacturing process, inspection, testing, identification and certification are properly conducted. As part of the Materials Survey Scheme, regular visits will be made to all relevant parts of the works to check for compliance against the requirements of these Rules, and to ensure that the manufacturer is maintaining the capability to consistently produce approved materials.

2.3.8 The Surveyor, when satisfied that the material fully meets the requirements of these Rules, will certify the material in accordance with Section 3 and the appropriate Chapter of these Rules.

2.3.9 For a manufacturer to maintain approval under this scheme, the works will be subject to a periodic inspection of all relevant parts of the works, at intervals not exceeding three years. The procedure for this periodic inspection is given in Book B of LR's *Materials and Qualification Procedures for Ships* (MQPS). This periodic inspection is in addition to the regular visits made according to 2.3.7.

2.4 Materials Quality Scheme

2.4.1 The manufacturer may apply to be approved under the Materials Quality Scheme, where the following requirements are met:

(a) The manufacturer has been approved by LR for a minimum of three years; and
(b) The manufacturer has a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum; and
(c) The manufacturer has a satisfactory history of quality performance in the manufacture and supply of LR approved materials.

2.4.2 Special consideration may be given to manufacturers who have not been approved under the Materials Survey Scheme, and may be considered onto the Materials Quality Scheme providing:

(a) They have a quality management system, which has been certified as meeting the requirements of ISO 9001 by a certification body recognised by LR, which is one accredited by a member of the International Accreditation Forum.
(b) They can demonstrate a history of satisfactory supply of materials, which LR deems to be equivalent to those for which approval under the Materials Quality Scheme is requested.

In this case, the initial assessment of the manufacturer will include the product testing regime, as required for initial approval under the Materials Survey Scheme, *see* 2.2.4.

2.4.3 The Scheme is based on a Scheme Certification Schedule, made between LR and each individual manufacturer. The schedule will stipulate:

(a) The scope of approved products covered by the approval.
(b) The process route applied by the manufacturer for each approved product.
(c) The arrangements for LR scheme, audits, including scope, frequency, schedule, etc.
(d) Agreed procedures for certification of approved materials.
(e) Information to be supplied periodically to LR by the manufacturer.
(f) Procedures for the use of the scheme mark.

2.4.4 The contents of the Scheme Certification Schedule are to remain confidential between LR and the manufacturer.

2.4.5 The Materials Quality Scheme is based on a technical audit approach, and is designed to complement the quality management systems audits performed to ISO 9001. The role of the Surveyor in scheme audits is to:

(a) Verify that the quality management system is being maintained and audited to the requirements of ISO 9001.
(b) Verify that the requirements of these Rules are being implemented.
(c) Verify that the requirements of this Scheme are being implemented.
(d) Perform Scheme audits, which focus on the technical aspects of the product realisation process, particularly with regard to Rule requirements.
(e) Perform witness testing as required.
(f) Verify the data supplied to LR periodically by the manufacturer, as part of the Scheme requirements.

2.4.6 The Materials Quality Scheme may be applied to any approved manufacturer who meets the eligibility requirements, and who applies to be approved under the scheme. If approved under the scheme, the manufacturer's name will appear on the List of Approved Manufacturers published by LR, with an indication that they are approved under this scheme.

2.4.7 The scheme is available to manufacturers producing approved materials according to Chapters 3 to 10 of these Rules.

2.4.8 The procedures for application for approval for the Materials Quality Scheme are given in Book M of LR's *Materials and Qualification Procedures for Ships* (MQPS).

2.4.9 Where LR is satisfied that the manufacturer meets all of the requirements of the Scheme, and that it is appropriate for the products being manufactured, a Scheme Certification Schedule will be issued, which must be signed by an authorised representative of the manufacturer.

2.4.10 Once the Scheme Certification Schedule has been signed by both parties, LR will issue the manufacturer with a certificate of approval according to the Materials Quality Scheme.

2.4.11 Maintenance of approval will be according to the Scheme Certification Schedule, agreed between LR and the manufacturer, and these Rules.

2.4.12 It is the responsibility of the attending Surveyor, to perform regular Scheme audits at the manufacturer's works in accordance with the Scheme Certification Schedule, and the requirements of these Rules.

2.4.13 It is not the intention to repeat the audit according to ISO 9001, conducted by the recognised certification body. The Surveyor is, however, to be satisfied that these audits are being conducted effectively. Where appropriate, the Surveyor may conduct a partial audit to ISO 9001 to verify this.

2.4.14 Witness tests may be conducted as part of the Scheme audit. This will involve the selection of material, and the witness of sampling and testing according to the requirements of the appropriate chapter of these Rules. Such witness testing may be on LR grades, or materials which the Surveyor deems to be equivalent (for the purposes of audit testing only).

2.4.15 Once every three years, a full assessment of scheme compliance will be conducted by a Surveyor who is not the regular attending Surveyor.

2.4.16 In the event of any change, which means that the manufacturer no longer meets the requirements for the Materials Quality Scheme (for example the loss of ISO 9001 approval), the Scheme certificate of approval will be revoked. The manufacturer will revert to the Materials Survey Scheme, and will be subject to survey according to that scheme.

■ *Section 3* Certification of materials

3.1 General

3.1.1 All materials subject to these Rules are to be supplied with appropriate certification, as required by the relevant requirements of these Rules. This will normally be a LR certificate or a manufacturer's certificate validated by LR, although a manufacturer's certificate may be accepted where allowed by the relevant requirements of these Rules.

3.1.2 Manufacturers approved under the Materials Quality Scheme are licensed to apply the scheme mark to manufacturer's certificates according to the requirements of the scheme, *see* 2.4.

3.1.3 The following certificate types are to be used, (a) and (b) for the Materials Survey Scheme, and (d) for the Materials Quality Scheme:

(a) **LR Certificate**
This type of certificate is issued by LR based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules.

(b) **Manufacturer's certificate validated by LR**
A manufacturer's certificate, validated by LR on the basis of inspection and testing carried out on the delivered product in accordance with the requirements of these Rules may be accepted. In this case, the certificate will include the following statement:
"We hereby certify, that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register."

(c) **Manufacturer's certificate**
This type of certificate is issued by the manufacturer, based on the results of testing and inspection being satisfactorily carried out in accordance with the requirements of these Rules, or the applicable National or International standard. The certificate is to be validated by the manufacturer's authorised representative, independent of the manufacturing department. The certificate will contain a declaration that the products are in compliance with the requirements of these Rules or the applicable National or International standard.

(d) **Manufacturer's certificate issued under the Materials Quality Scheme**
Where a manufacturer is approved according to the Materials Quality Scheme, they will issue manufacturer's certificates bearing the scheme mark. The certificates must also bear the following statement:
"This certificate is issued under the arrangements authorised by Lloyd's Register (operating group) in accordance with the requirements of the Materials Quality Scheme and certificate number MQS ...."

3.1.4 Where these Rules allow for the issue of a manufacturer's certificate for materials, either validated by an LR Surveyor, or bearing the Materials Quality Scheme mark, the manufacturer is to ensure that a copy of the certificate is supplied to LR.

3.2 Materials Survey Scheme

3.2.1 The requirements for certification of materials according to the Materials Survey Scheme, are established by the relevant requirements of these Rules.

3.2.2 The manufacturer is to supply the surveyor with any additional customer order requirements that are in addition to the requirements of these Rules, when the request for the issue or validation of the certificate is made.

3.3 Materials Quality Scheme

3.3.1 Part of the certification schedule, will include an agreement for the manufacturer, to apply the scheme mark to manufacturer's certificates, relating to approved products within the scope of approval of the manufacturer.

3.3.2 The use of the scheme mark is governed by the following:

(a) The use of the scheme mark is not transferable. It is only to be used in conjunction with the manufacturer and works name and location shown on the certificate of approval.
(b) The scheme mark must be applied to all manufacturers' certificates relating to approved materials produced under the Scheme.
(c) In no circumstances is the scheme mark to be applied to test certificates relating to non-approved products.
(d) The scheme mark is not to be used in any way which may imply approval for products which are not covered within the manufacturer's scope of approval.

(e) Where a manufacturer is removed or suspended from the scheme, use of the scheme mark must cease immediately.

3.3.3 The certificate as given in 3.1.3(d) is to be validated by an authorised representative of the manufacturer. The size and position of the scheme mark and statement on the manufacturer's certificate must be agreed by LR.

3.3.4 Where manufacturers are approved under this scheme, the manufacturer's certificate, issued according to these requirements, fully meets the materials certification requirements of these Rules.

3.4 Electronic certification

3.4.1 Where these Rules allow the issue of manufacturers' test certificates, under either the Materials Survey Scheme or the Materials Quality Scheme, these may be issued in electronic format provided that:

(a) All tests and inspections have been satisfactorily completed, according to the requirements of these Rules.
(b) Procedures are in place to ensure that electronic certificates are only issued, according to the requirements of these Rules.
(c) The certification system is subject to regular inspection by the attending Surveyor.
(d) A copy of the electronic certificate is supplied to LR. This copy will be deemed to be the original of the test certificate.

3.4.2 In addition to the requirements of 3.4.1, for items certified under the Materials Survey Scheme, the LR office stamp and Surveyor's name may be applied electronically. This is only allowed where the Surveyor has access to the results of the relevant tests and inspections, and is able to authorise by access to the electronic system, the application of the LR office stamp and Surveyor's name on the test certificate. The name of the authorising Surveyor is to be the name included on the certificate. The authorisation may be conducted electronically either at the manufacturers' works, or remotely by the Surveyor.

3.4.3 If the LR office stamp and name are being applied electronically according to 3.4.2, then the manufacturer is to ensure that the Surveyor is provided with all relevant information regarding the customer order, when the request for authorisation is made.

■ *Section 4*
General requirements for manufacture

4.1 General

4.1.1 The following definitions are applicable to these Rules:

Item: A single forging, casting, plate, tube or other rolled product as delivered.

Piece: The rolled product from a single slab or billet or from a single ingot if this is rolled directly into plates, strip, sections or bars.

Batch: A number of similar items or pieces presented as a group for acceptance testing.

Wide flat: Flat product of a width over 150 mm, up to and including 1250 mm and thickness generally over 4 mm. Edges are square cut, i.e., hot rolled on the four sides. Supplied in lengths, not coils.

Plate/sheet: Flat rolled product whereby the edges are allowed to deform freely. Supplied flat and generally in square or rectangular shapes with a width of 600 mm or over, but other shapes may also apply.

4.1.2 Where a manufacturer purchases semi-finished products (e.g., slabs) for the purpose of re-processing (e.g., rolling), the manufacturer is to ensure that the materials are from an LR approved manufacturer, and manufactured within the scope of approval of that manufacturer. The aim of chemical analysis, dimensions, surface and internal quality checks are to be agreed between the manufacturer and purchaser. The semi-finished materials must be supplied with appropriate certification, according to these Rules.

4.1.3 It is the responsibility of the manufacturer, to ensure compliance with all relevant aspects of these Rules. All deviations are to be recorded as non-compliances, and brought to the attention of the Surveyor, along with corrective actions taken. Failure to do this is considered to render the material as not complying with these Rules.

4.1.4 The manufacturer is to maintain all test and inspection records required by these Rules for at least seven years. Records are to be made available to LR on request.

4.1.5 Where material is produced which does not meet all aspects of these Rules, the manufacturer may apply to LR for a concession to certify the material as approved. LR will consider each application on a case-by-case basis, although concession will only normally be granted in exceptional circumstances. If the concession is granted, a formal written numbered concession will be issued to the manufacturer. The concession number must be applied to the approval certificate, whether it is an LR certificate or a validated manufacturer's certificate.

4.2 Chemical composition

4.2.1 The ladle analysis used for certification purposes is to be determined after all alloying elements have been added and sufficient time allowed for such additions to equalise throughout the ladle.

4.2.2 The method of taking samples is to ensure that the reported analysis is representative of the cast. In addition, the manufacturer must determine and certify the chemical composition of every heat of material.

4.2.3 Where more than one sample is taken, the method of averaging for the final certificate result and the determination of acceptable variations in composition are to be agreed with the Surveyor.

4.2.4 The chemical composition of ladle samples is to be determined by the manufacturer in an adequately equipped and competently staffed laboratory. The manufacturer's analysis will be accepted, but may be subject to occasional independent checks if required by the Surveyor.

4.2.5 The analysis is to include the content of all the elements detailed in the relevant Sections of the Rules and, where appropriate, the National or International Standard applied.

4.2.6 At the discretion of the Surveyors, a check chemical analysis of suitable samples from products may also be required. These samples are to be taken from the material used for mechanical tests but, where this is not practicable, an alternative procedure for obtaining a representative sample is to be agreed with the manufacturer. For product samples, the permissible limits of deviation from the specified ladle analysis are to be in accordance with an appropriate International or National Standard specification.

4.3 Heat treatment

4.3.1 Materials are to be supplied in the condition specified in, or permitted by, the relevant Chapters of these Rules.

4.3.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components, which require heat treatment, alternative methods will be specially considered.

4.3.3 The manufacturer is to maintain the records, including the temperature charts of all heat treatments, for at least seven years.

4.4 Test material

4.4.1 Sufficient test material is to be provided for the preparation of the test specimen detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

4.4.2 The test material is to be representative of the item or batch and is not to be separated until all the specified heat treatment has been completed, except where provision for an alternative procedure is made in subsequent Chapters of these Rules.

4.4.3 All test material is to be selected by the Surveyor or an authorised deputy and identified by suitable markings which are to be maintained during the preparation of the test specimens.

4.5 Mechanical tests

4.5.1 The dimensions, number and direction of test specimens are to be in accordance with the requirements of Chapter 2 and the specific requirements for the product.

4.5.2 Where Charpy impact tests are required, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Chapters. One individual value may be less than the required average value, provided that it is not less than 70 per cent of that value.

4.5.3 In the Rules, mechanical properties are specified in SI units, but alternative units may be used for acceptance testing. In such cases, the specified values are to be converted in accordance with the appropriate conversions given in Table 1.4.1. It is preferred that test results be reported in SI units, but alternative units may be used provided that the test certificate gives, in the same units, the equivalent specification values.

Table 1.4.1 Conversions from SI units to metric and Imperial units

1 N/mm^2 or MPa	=	0,102 kgf/mm^2
1 N/mm^2 or MPa	=	0,0647 tonf/in^2
1 N/mm^2 or MPa	=	0,145 x 10^3 lbf/in^2
1J	=	0,102 kgf m
1J	=	0,738 ft lbs
1 kgf/mm^2	=	9,81 N/mm^2 or MPa
1 tonf/in^2	=	15,4 N/mm^2 or MPa
1 lbf/in^2	=	6,89 x 10^{-3} N/mm^2 or MPa
1 kgf m	=	9,81 J
1 ft lbf	=	1,36 J

4.6 Re-test procedures

4.6.1 Re-test procedures are to be in accordance with the requirements of Ch 2,1.4.

4.7 Rectification of defective material

4.7.1 Small surface imperfections may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from defects and the rectification has been completed in accordance with any applicable requirements of subsequent Chapters of these Rules and to the satisfaction of the Surveyor.

4.7.2 The repair of defects by welding, can be accepted only when permitted by the appropriate specific requirements and provided that the agreement of the Surveyor is obtained before the work is commenced. When a repair has been agreed, it is necessary in all cases to prove by suitable methods of non-destructive examination that the defects have been completely removed before welding is commenced. Welding procedures and inspection on completion of the repair, are to be in accordance with the appropriate specific require-ments and are to be to the satisfaction of the Surveyor.

4.7.3 Manufacturers wishing to carry out welding work must have at their disposal the necessary workshops, lifting gear, welding equipment, pre-heating, and where necessary annealing facilities and testing devices, as well as certified welders and supervisors to enable them to perform the work properly. Proof shall be furnished to the Surveyor that these conditions are satisfied before welding work begins.

4.8 Identification of materials

4.8.1 The manufacturer is to adopt a system of identification, which will enable all finished materials to be traced to the original cast, and the Surveyors are to be given full facilities for tracing the material when required. When any item has been identified by the personal mark of a Surveyor, or his deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

4.8.2 Before any item is finally accepted, it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements.

4.8.3 Where hard stamps such as the LR brand stamp are issued to manufacturers to carry out the stamping on behalf of LR, the procedure for issue, maintenance and use of stamps is to be agreed in writing.

4.8.4 Hard stamping is to be used except where this may be detrimental to the material, in which case stencilling, painting or electric etching is to be used. Paints used to identify alloy steels are to be free from lead, copper, zinc or tin, i.e., the dried film is not to contain any of these elements in quantities of more than 250 ppm.

4.8.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

■ *Section 5* Non-destructive examination

5.1 General NDE requirements

5.1.1 Prior to the final acceptance of materials, surface inspection and verification of dimensions, non-destructive examination is to be carried out in accordance with the requirements detailed in this Section and subsequent Chapters of these Rules.

5.1.2 It is the manufacturer's responsibility for maintaining the required tolerances and making the necessary measurements. Periodic surveys by the Surveyor do not absolve the manufacturer from this responsibility.

5.1.3 When there is visible evidence to doubt the soundness of any material or component, such as flaws in test specimens or suspicious surface marks, the manufacturer is expected to prove the quality of the material by a suitable method.

5.1.4 Acceptance criteria are detailed in subsequent Chapters of these Rules. Alternative specifications may be submitted for consideration, provided they demonstrate equivalence to these Rules.

5.2 Personnel qualifications

5.2.1 The shipyard, fabricator or manufacturer is to ensure that personnel carrying out non-destructive examination or interpreting the results of non-destructive examination are qualified to the appropriate level of a nationally recognised scheme such as ISO 9712, EN 473, PCN, ACCP or SNT-TC-1A. Level 1 personnel are not permitted to interpret results to Codes or Standards.

5.2.2 When certification of personnel is made on an in-house basis under a scheme such as SNT-TC-1A, practical examinations are to be relevant to material, product type, joint configuration, material thickness and acceptance criteria of items inspected for Classification purposes.

5.2.3 Personnel qualifications of NDE operators are to be randomly checked by the Surveyor.

5.3 Non-destructive examination methods

5.3.1 Non-destructive examination methods are to comply with the relevant requirements of these Rules.

5.4 Non-destructive examination procedures

5.4.1 All non-destructive examinations are to be carried out to a procedure that is representative of the item under inspection. As a minimum the procedures are to be in accordance with the following:

(a) Procedures are to identify the component to be examined, the NDE method, equipment to be used and the full extent of the examinations including any test restrictions.
(b) Procedures are to specify the qualification and certification requirements of the inspection personnel to be employed.
(c) Procedures are to state the degree of surface preparation required and the methods of preparation to be used before the examinations are made.
(d) Procedures are to state the reference standards for testing and the acceptance criteria to be applied to the results of the inspections.
(e) Procedures are to include the requirement for components to be positively identified and for a datum system or marking system to be applied to ensure repeatability of inspections.
(f) Procedures are to identify any requirements for increasing the extent of applied NDE where defects have been found during spot examination.
(g) Procedures are to identify reporting requirements.
(h) Procedures are to be reviewed by the Surveyor to ensure they are appropriate for the product type.
(j) Procedures for radiography are to specify the acceptable optical density within the area of interest on the radiograph.
(k) The minimum optical density within the area of interest on a radiograph is to be equal to or greater than 2,0 for gamma ray and 1,8 for X-ray. A maximum density of 4,0 is acceptable.
(l) Procedures are to include the method and requirements for equipment calibrations and functional checks.
(m) Procedures are to be approved by an operator qualified to a minimum of Level III in accordance with a recognised standard.
(n) The Surveyor will review procedures for compliance with this Section.

5.4.2 The shipyard, fabricator or manufacturer may submit other Codes or Standards for consideration by LR, providing they are equivalent to these Rules. Where no agreed acceptance standard is in place, the acceptance levels contained in the subsequent Chapters of these Rules are to apply.

5.4.3 In the event that proposed acceptance criteria are not considered to be equivalent to these Rules, the criteria may be submitted for special consideration.

5.5 Non-destructive examination reports

5.5.1 NDE reports are to include all information required to identify how the examination was executed and are to include the following information where appropriate:

(a) Date of test.
(b) Name and qualification of operator with signatures of the operator.
(c) Details of the component identification, description of test location and volume examined.
(d) Heat treatment status.
(e) Weld type, procedure and configuration.
(f) Surface condition.
(g) Test procedure.
(h) Equipment used.
(j) Test results with a map or record of reportable and/or reject indications, giving location, dimensions and nature of indications.
(k) Reference to acceptance criteria and evaluation in accordance to these criteria.
(l) Material type and thickness.
(m) Calibration.

■ *Section 6* References

6.1 General

6.1.1 The locations of National and International Standards referenced in these Rules are shown in Table 1.6.1.

Table 1.6.1 List of National and International Standards

Rule reference	Standard
Chapter 1 – General Requirements	ISO 9001: 2008
Chapter 2 – Testing Procedures for Metallic Materials	ISO 6892-1: 2009 ISO 185: 2005 ISO 2566-1: 1999 ISO 148-1: 2009 ISO 7500-1: 2004 ASTM E23-07ae1
Chapter 3 – Rolled Steel Plates, Strip, Sections and Bars	EN 10160: 1999 ASTM A578-07 ASTM E112-96 (2004)e2 ASTM E381-01 (2006) ASTM A255-10
Chapter 4 – Steel Castings	ISO 1161: 1984/Amendment 1: 2007
Chapter 5 – Steel Forgings	ASTM E112-10
Chapter 8 – Aluminium Alloys	ASTM G66-99 (2005)e1 ASTM G67-04
Chapter 9 – Copper Alloys	ASTM E272-10
Chapter 10 – Equipment for Mooring and Anchoring	ISO 1704: 2008 ISO 1834: 1999 ISO 4565: 1986 ASTM E112-10 ASTM E381-01 (2006) ASTM A255-10
Chapter 11 – Approval of Welding Consumables	ISO 3690: 2000 ISO 10042: 2005 ASTM G48-03 (2009)
Chapter 12 – Welding Qualifications	ISO 6947: 1997 ISO 5817: 2007 ISO 6520-1: 2007 ISO 6507-1: 2005 ISO 10042: 2005
Chapter 13 – Requirements for Welded Construction	ISO 9712/Cor1: 2006 EN 473: 2008 ISO 6520-1: 2007 SNT-TC-1A: 2006 ISO 10042: 2005
Chapter 14 – Plastics Materials	ISO 527-2: 1993/corr1:1994 ISO 178: 2010 ISO 62: 2008 ISO 75-2: 2004 ISO 604: 2002 ISO 527-4: 1997 ISO 14125: 1998/ amd1:2011 ISO 14130: 1997/ corr1:2003 ISO 1172: 1996 ISO 1922- 2001 ASTM C273/C273M-07[a] ASTM C393/C393M-06 ISO 845- 2006 ASTM C297/C297M-04 ISO 844-2007 ISO 1922-2001 ISO 180-2000 ASTM D2583-07 BS 2782-10 Method 1001: 1977 ISO 175: 2010

Testing Procedures for Metallic Materials

Section

■ *Section 1* General requirements for testing

1.1 Preparation of test specimens

1.1.1 The requirements specified below detail all the tests that may be applied to metallic materials. The specific tests and the test specimen types required for each material type, grade and product type are detailed in the subsequent Chapter of these Rules.

1.1.2 Where test material is cut from products by shearing or flame cutting, a reasonable margin is required to allow sufficient material to be removed from the cut edges during machining of the test specimens.

1.1.3 Test specimens are to be prepared in such a manner that they are not subjected to any significant work hardening, cold straining or heating during straightening or machining.

1.1.4 Test samples are not to be removed from the material they represent until heat treatment is complete. For castings in cases where test samples are separately cast, the castings and samples are to be heat treated together.

1.1.5 Dimensional tolerances are to comply with a relevant ISO specification.

1.2 Testing machines

1.2.1 All tests are to be carried out by competent personnel. Testing machines are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. This calibration is to be carried out by organisations of standing that have been approved or recognised by a National Authority and are to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house.

1.2.2 Tensile testing machine load cells are to be calibrated with an accuracy of ± one per cent in accordance with ISO 7500-1 or another recognised National Standard.

1.2.3 Impact tests are to be carried out on Charpy V-notch machines calibrated to ISO 148 or ASTM E23 dependent on the testing machine type. The testing machines are to be calibrated using either a direct or indirect method. Other National Standards equivalent to ISO 148 may be considered.

1.3 Discarding of test specimens

1.3.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine it may be discarded and replaced by a new test specimen prepared from material adjacent to the original test.

1.3.2 In addition to the discarding of test specimens as indicated in 1.3.1, a tensile test specimen may also be discarded when the specified minimum elongation is not obtained and the distance between the fracture and the nearest gauge mark is less than one-quarter of the gauge length.

1.4 Re-testing procedures

1.4.1 Where the result of any test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same test sample, or if sufficient material is not available, a further representative sample taken from the item under test. For acceptance of the material, satisfactory results are to be obtained from both of these additional tests.

1.4.2 Where the result of any test taken from a weld procedure approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using the same conditions as the original test weld. For acceptance, satisfactory results are to be obtained from both of these additional tests.

1.4.3 Where the result of any test taken from a welding consumable approval test, other than an impact test, does not comply with the requirements, two additional tests of the same type are to be made from the same weld test assembly. Where insufficient original welded assembly is available, a new assembly is to be prepared using welding consumables from the same batch. If the new assembly is made with the same procedure (particularly the same number of runs) as the original assembly, only the duplicate re-test specimens need be prepared and tested. For acceptance of a weld consumable batch, satisfactory results are to be obtained from both of these additional tests.

1.4.4 Where the results from a set of three impact test specimens do not comply with the requirements, an additional set of three impact test specimens may be tested provided that, of the original set tested, not more than two individual values are less than the required average value and, of these, not more than one is less than 70 per cent of this average value. The results obtained are to be combined with the original results to form a new average which, for acceptance, is to be not less than the required average value. Additionally, for these combined results, not more than two individual values are to be less than the required average value and, of these, not more than one is to be less than 70 per cent of this average value.

1.4.5 The additional tests detailed in 1.4.1 and 1.4.2 are, where possible, to be made on material adjacent to the original samples. For castings, where insufficient material remains in the original test samples, the additional test may be made on other test samples representative of the castings. *See also* 1.3 for discarding of test specimens.

1.4.6 When unsatisfactory results are obtained from tests representative of a batch of material, the item or piece from which the tests were taken is to be rejected. The remainder of the material in the batch may be accepted provided that two further items or pieces are selected and tested with satisfactory results. If the tests from one or both or these additional items or pieces give unsatisfactory results, the batch is to be rejected.

1.4.7 When a batch of material is rejected, the remaining items or pieces in the batch may be resubmitted individually for test, and those which give satisfactory results may be accepted.

1.4.8 At the option of the manufacturer, rejected material may be resubmitted as another grade and may then be accepted, provided that the test results comply with the appropriate requirements.

1.4.9 When material which is intended to be supplied in the 'as-rolled' or 'hot-finished' condition fails test, it may be suitably heat treated and resubmitted for test. Similarly, materials supplied in the heat treated condition may be reheat treated and resubmitted for test. Unless otherwise agreed by the Surveyor, such reheat treatment is to be limited to one repeat of the final heat treatment cycle.

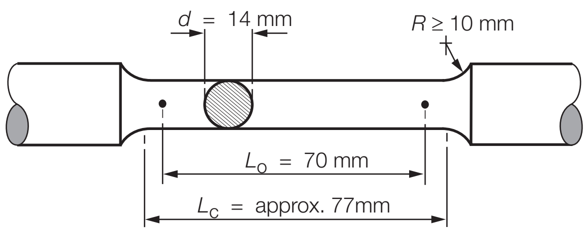
■ *Section 2*
Tensile tests

2.1 Dimensions of test specimens

2.1.1 Proportional test specimens with a gauge length L_o of $5{,}65\sqrt{S_o}$ or $5d$, where S_o is the cross-sectional area, d the diameter and L_c the parallel test length, have been adopted as the standard form of test specimen, and in subsequent Chapters in these Rules the minimum percentage elongation values are given for test specimens of these proportions.

2.1.2 The gauge length is to be greater than 20 mm and may be rounded off to the nearest 5 mm provided that the difference between the adjusted gauge length and the calculated one is less than 10 per cent of the calculated gauge length.

2.1.3 For forgings and castings (excluding those in grey cast iron) proportional test specimens of circular cross-section are to be machined to the dimensions shown in Fig. 2.2.1.

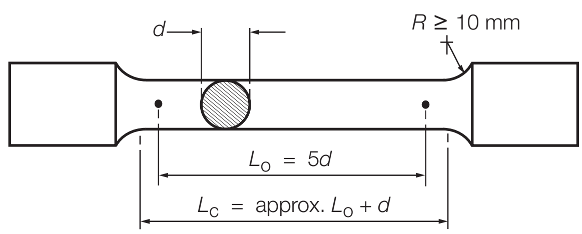


NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 20$ mm

Fig. 2.2.1
Test specimen dimensions for forgings and castings – I

2.1.4 For hot rolled bars and similar products, the test specimens are to be as in Fig. 2.2.1, except that for small sizes they may consist of a suitable length of bar or other product tested in the full cross-section.

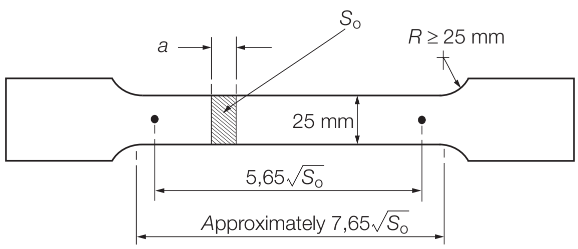
2.1.5 As an alternative to 2.1.3 and 2.1.4, proportional or non-proportional test specimens of other dimensions may be used, subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. Where the size of proportional test specimens is other than as shown in Fig. 2.2.1, the general dimensions are to conform with Fig. 2.2.2.



NOTE: For nodular cast iron and materials with a specified elongation less than 10%, $R \geq 1{,}5d$

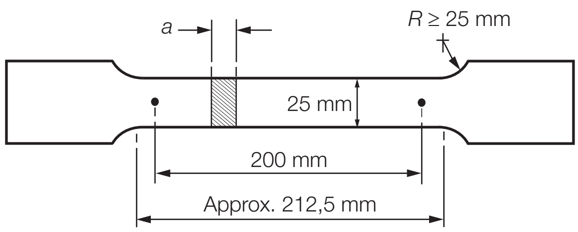
Fig. 2.2.2
Test specimen dimensions for forgings and castings – II and aluminium alloys

2.1.6 For plates, strip and sections, the test specimens are to be machined to the dimensions shown in Fig. 2.2.3 or Fig. 2.2.4. Where the capacity of the available testing machine is insufficient to allow the use of a test specimen of full thickness, this may be reduced by machining one of the rolled surfaces. Alternatively, for materials over 40 mm thick, test specimens of circular cross-section machined to the dimensions shown in Fig. 2.2.1 may be used. The axes of these test specimens are to be located at approximately one quarter of the thickness from one of the rolled surfaces.



a = thickness of material

Fig. 2.2.3
Test specimen dimensions for plates, strip and sections – I and aluminium alloys



a = thickness of material

Fig. 2.2.4
Test specimen dimensions for plates, strip and sections – II

2.1.7 As an alternative to 2.1.6, test specimens with a width of other than 25 mm may be used subject to any requirements for minimum cross-sectional area given in subsequent Chapters of these Rules. A ratio of width/ thickness of 8:1 should not be exceeded.

2.1.8 For pipes and tubes, the test specimens may consist of a suitable length tested in full cross-section with the ends plugged. The gauge length is to be $5{,}65\sqrt{S_o}$ or 50 mm, and the length of the test specimen between the grips or plugs, whichever is the smaller, is to be not less than the gauge length plus D, where D is the external diameter. Alternatively, test specimens may be prepared from strips cut longitudinally and machined to the dimensions shown in Fig. 2.2.5 or Fig. 2.2.6. The parallel test length is not to be flattened, but the enlarged ends may be flattened for gripping in the testing machine.

The cross-sectional area of this type of test specimen is to be calculated from:

$S_o = ab$

where

S_o = cross-sectional area
a = average radial thickness
b = average width

Test specimens of circular cross-section may also be used provided that the wall thickness is sufficient to allow the machining of such specimens to the dimensions shown in Fig. 2.2.1, with their axes located at the mid-wall thickness.

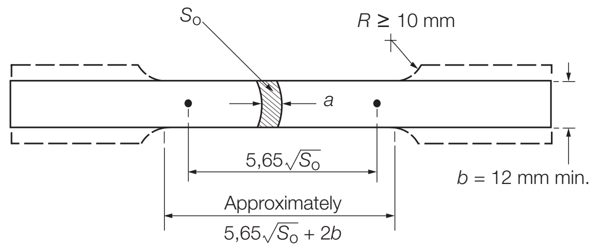


Fig. 2.2.5
Test specimen dimensions for pipes and tubes – I

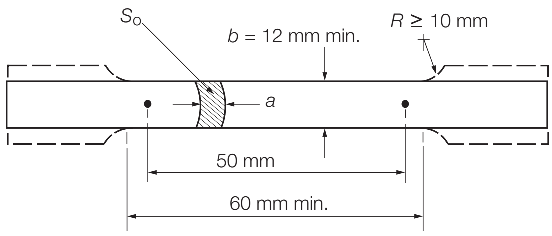


Fig. 2.2.6
Test specimen dimensions for pipes and tubes – II

2.1.9 For wire, the test specimen may consist of a suitable length tested in full cross-section. The gauge length is to be 200 mm and the parallel test length 250 mm.

2.1.10 For grey iron castings, the test specimens are to be machined to the dimensions shown in Fig. 2.2.7 or Fig. 2.2.8.

2.1.11 For aluminium alloy plates and sections of thickness, a, less than or equal to 12,5 mm; the dimensions of rectangular cross-sectioned test specimens are to be as shown in Fig. 2.2.3. The rectangular cross-sectioned test specimen surfaces should remain as rolled/extruded. Where the thickness, a, is greater than 12,5 mm the test specimens are to be of round type as shown in Fig. 2.2.2.

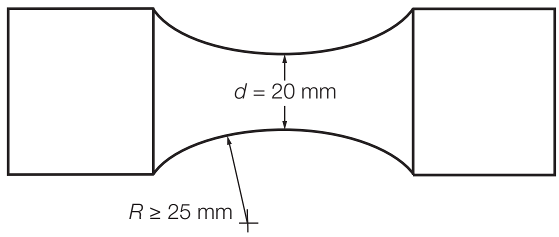


Fig. 2.2.7
Test specimen dimensions for grey iron castings – I

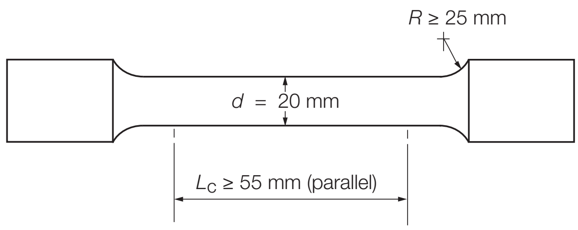


Fig. 2.2.8
Test specimen dimensions for grey iron castings – II

2.1.12 Deposited weld metal tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.9, and may be heated to a temperature not exceeding 250°C for a period not exceeding 16 hours for hydrogen removal, prior to testing.

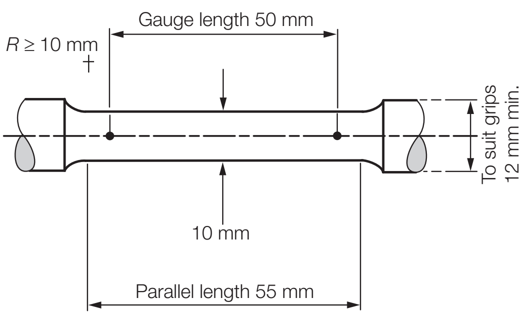


Fig. 2.2.9
Test specimen for deposited weld metal tensile

2.1.13 Butt weld tensile test specimens are to be machined to the dimensions shown in Fig. 2.2.10. For thicknesses of more than 2 mm, the test width is to be 25 mm. For thicknesses less than 2 mm, the test width is to be reduced to 12 mm. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

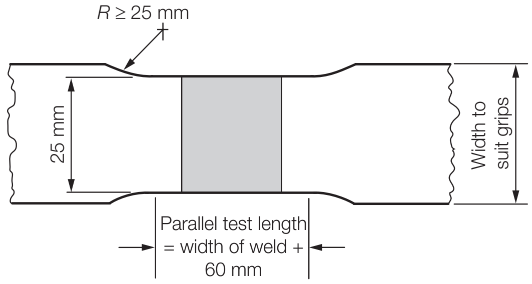


Fig. 2.2.10 Test specimen for butt weld

2.1.14 Through-thickness tensile test specimens may be, at the option of the steelmaker, either plain test specimens or test specimens with welded extensions in accordance with a Recognised Standard. The extension pieces are to be of steel with a tensile strength exceeding that of the plate to be tested and may be attached to the plate surfaces by manual, resistance or friction welding carried out in such a way as to ensure a minimal heat affected zone.

2.1.15 Tolerances on tensile specimen dimensions are to be in accordance with ISO 6892-1 or another Recognised Standard as appropriate.

2.2 Definition of yield stress for steel

2.2.1 The yield phenomenon is not exhibited by all the steels detailed in these Rules but, except for austenitic and duplex stainless steels, the term ‘yield stress’ is used throughout when requirements are specified for acceptance testing at ambient temperature. For the purposes of the Rules, the terms ‘yield stress’ and ‘yield strength’ are to be regarded as synonymous.

2.2.2 Where reference is made to ‘yield stress’ in the requirements for carbon, carbon-manganese and alloy steel products and in the requirements for the approval of welding consumables, either the upper yield stress or, where this is not clearly exhibited, the 0,2 per cent proof stress or the 0,5 per cent proof stress under load is to be determined. In cases of dispute, the 0,2 per cent proof stress is to be determined.

2.2.3 For austenitic and duplex stainless steel products and welding consumables, both the 0,2 and the 1,0 per cent proof stresses are to be determined.

2.3 Procedure for testing at ambient temperature

2.3.1 Except as provided in 2.3.5, the elastic stress rate for the determination of the upper yield for steels and copper alloys is to be between 6 and 60 N/mm^2 per second and between 2 and 20 N/mm^2 per second for aluminium. After reaching the yield or proof load, the straining rate may be increased to a maximum of 0,008s^{-1} for the determination of the tensile strength.

2.3.2 For steel, the upper yield stress is to be calculated from:

(a) the value of stress measured at the commencement of plastic deformation, or

(b) on a load/extension diagram using the value of stress measured at the first peak obtained during yielding even when the peak is equal to or less than any subsequent peaks observed during plastic deformation at yield.

2.3.3 When a well defined yield point cannot be obtained, the 0,2 or 1,0 per cent proof stress (non-proportional elongation) is to be determined from an accurate load/extension diagram by drawing a line parallel to the straight elastic portion and a distance from it where the amount represents 0,2 or 1,0 per cent of the extensometer gauge length. The point of intersection of this line with the plastic portion of the diagram represents the proof load, from which the 0,2 or 1,0 per cent proof stress can be calculated.

2.3.4 For stainless steels, the 1,0 per cent proof stress and/or 0,2 per cent proof stress is specified as required by the relevant Chapters in these Rules.

2.3.5 For the determination of the tensile strength of flake graphite cast iron, the stress rate is not to exceed 10 N/mm^2 per second.

2.3.6 A measured elongation value is to be regarded as valid only if the fracture occurs within the gauge length and at least the following distances from the gauge marks:

Round test specimen:	1,25*d*
Flat test specimen:	*a* plus width of specimen

The measurement is valid irrespective of the position of the fracture, if the percentage elongation after fracture reaches at least the specified value, and this is to be stated in the test report.

2.4 Equivalent elongations

2.4.1 When a gauge length other than 5,65 $\sqrt{S_o}$ is used, the equivalent percentage elongation value is to be calculated using the following formula:

$$A = \frac{A_R}{2}\left(\frac{L_o}{\sqrt{S_o}}\right)^{0,40}$$

where

A_R = actual measured percentage elongation of test specimen

S_o = actual cross-sectional area of test specimen

L_o = actual gauge length of test piece

A = equivalent percentage elongation for a test specimen with a gauge length of 5,65 $\sqrt{S_o}$

2.4.2 Alternatively, where a number of test specimens of similar material and dimensions are involved, the actual percentage elongation values may be recorded, provided that the equivalent specified minimum elongation value appropriate for the test specimen dimensions is calculated from the formula in 2.4.1 and is recorded on the test certificate.

2.4.3 For proportional test specimens having a gauge length other than 5,65$\sqrt{S_o}$, the equivalent elongation may be calculated using the following factors (*d* is the diameter of the test specimen):

Actual gauge length	Factor for equivalent elongation on 5,65$\sqrt{S_o}$
4 $\sqrt{S_o}$	x 0,870
8,16 $\sqrt{S_o}$	x 1,158
11,3 $\sqrt{S_o}$	x 1,317
4*d*	x 0,916
8*d*	x 1,207

2.4.4 For non-proportional test specimens with gauge lengths of 50 mm and 200 mm, the equivalent elongation values tabulated in ISO 2566 are to apply.

2.4.5 The above conversions are reliable only for carbon, carbon-manganese and low alloy steels with a tensile strength not exceeding 700 N/mm^2 in the hot rolled, annealed, normalised, or normalised and tempered condition.

2.4.6 For alloy steels in the quenched and tempered condition, the following conversions may be used for proportional test specimens with a gauge length of 4$\sqrt{S_o}$:

Actual percentage elongation on 4$\sqrt{S_o}$	Equivalent elongation on 5,65$\sqrt{S_o}$
22	17
20	15
18	13
17	12
16	12
15	11
14	10
12	8
10	7
8	5

2.4.7 Any proposals to use conversion factors for equivalent elongation values for the following materials are to be agreed with the Surveyors:

(a) Carbon, carbon-manganese and alloy steels in the normalised or normalised and tempered condition with a tensile strength exceeding 700 N/mm^2.

(b) Cold-worked steels.

(c) Austenitic stainless steels.

(d) Non-ferrous alloys.

2.5 Procedure for testing at elevated temperatures

2.5.1 The test specimens used for the determination of lower yield or 0,2 per cent proof stress at elevated temperatures are to have an extensometer gauge length of not less than 50 mm and a cross-sectional area of not less than 65 mm^2. Where, however, this is precluded by the dimensions of the product or by the test equipment available, the test specimen is to be of the largest practicable dimensions.

2.5.2 The heating apparatus is to be such that the temperature of the specimen during testing does not deviate from that specified by more than ±5°C.

2.5.3 The straining rate when approaching the lower yield or proof load is to be controlled within the range 0,1 to 0,3 per cent of the extensometer gauge length per minute.

2.5.4 The time intervals used for estimation of strain rate from measurements of strain are not to exceed 6 seconds.

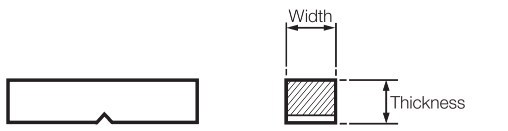
■ *Section 3* Impact tests

3.1 Dimensions of test specimens

3.1.1 Impact tests are to be of the Charpy V-notch type. The test specimens are to be machined to the dimensions and tolerances given in Table 2.3.1 and are to be carefully checked for dimensional accuracy.

Table 2.3.1 Dimensions and tolerances for Charpy V-notch impact test specimens

Dimension	Nominal	Tolerance
Length, mm	55	±0,60
Width, mm– standard specimen	10	±0,11
– standard subsidiary specimen	7,5	±0,11
– standard subsidiary specimen	5	±0,06
Thickness, mm	10	±0,06
Angle of notch	45°	±2°
Depth below notch, mm	8	±0,06
Root radius, mm	0,25	±0,025
Distance of notch from end of test specimen, mm	27,5	±0,42
Angle between plane of symmetry of notch and longitudinal axis of test specimen	90°	±2°



3.1.2 For material under 10 mm in thickness, the largest possible size of standard subsidiary Charpy V-notch test specimen is to be prepared with the notch cut on the narrow face. Generally, impact tests are not required when the thickness of the material is less than 6 mm.

3.2 Testing procedures

3.2.1 All impact tests are to be carried out on Charpy machines approved by Lloyd's Register (hereinafter referred as LR) and having a striking energy of not less than 150 J.

3.2.2 Charpy V-notch impact tests may be carried out at ambient or lower temperatures in accordance with the specific requirements given in subsequent Chapters of these Rules. Where the test temperature is other than ambient, the temperature of the test specimen is to be controlled to within ±2°C for sufficient time to ensure uniformity throughout the cross-section of the test specimen, and suitable precautions are to be taken to prevent any significant change in temperature during the actual test. In cases of dispute, ambient temperature is to be considered as 18°C to 25°C.

3.2.3 For acceptance, the average energy value for a set of three impact tests must be equal to or greater than the appropriate specified minimum average value. Additionally, only one individual value may be less than the required average value but not less than 70 per cent of this average value.

3.2.4 Where standard subsidiary Charpy V-notch test specimens are necessary, the minimum energy values required are to be reduced as follows:

Specimen 10 x 7,5 mm: 5/6 of tabulated energy.
Specimen 10 x 5 mm: 2/3 of tabulated energy.

3.2.5 When reporting results, the specimen dimensions and the units used for expressing the energy absorbed (Joules) and the testing temperature are to be clearly stated.

■ *Section 4* Ductility tests for pipes and tubes

4.1 Bend tests

4.1.1 The test specimens are to be cut as circumferential strips of full wall thickness and with a width of not less than 40 mm. For thick walled pipes, the thickness of the test specimens may be reduced to 20 mm by machining. The edges of the specimens may be rounded to a radius of 1,6 mm.

4.1.2 Testing is to be carried out at ambient temperature, and the specimens are to be doubled over a former whose diameter is to be in accordance with the specific requirements for the material. For submerged arc welded tube the test piece is to be bent with the root of the weld in tension. For other tubes, the test piece is to be bent in the original direction of curvature. In all cases, the welds are to be in the middle of the test specimen. The test is considered to be satisfactory if, after bending, the specimens are free from cracks and laminations. Small cracks at the edges of the test specimens are to be disregarded.

4.2 Flattening tests

4.2.1 Ring test specimens are to be cut with the ends perpendicular to the axis of the pipe or tube. The length of the specimen is to be equal to 1,5 times the external diameter of the pipe or tube, but is to be not less than 10 mm or greater than 100 mm. Alternatively, the length of the test specimen may be 40 mm irrespective of the external diameter.

4.2.2 Testing is to be carried out at ambient temperature and is to consist of flattening the specimens in a direction perpendicular to the longitudinal axis of the pipe. Flattening is to be carried out between two plain parallel and rigid platens which extend over both the full length and the width after flattening of the test specimen. Flattening is to be continued until the distance between the platens, measured under load, is not greater than the value given by the formula:

$$H = \frac{t\,(1 + C)}{C + \frac{t}{D}}$$

where
H = distance between plates, in mm
t = specified thickness of the pipe, in mm
D = specified outside diameter, in mm
C = a constant dependent on the steel type and detailed in the specific requirements

After flattening, the specimens are to be free from cracks or other flaws. Small cracks at the ends of the test specimens may be disregarded.

4.2.3 For welded pipes or tubes, the weld is to be placed at 90° to the direction of flattening.

4.3 Drift expanding tests

4.3.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The edges of the end to be tested may be rounded by filing.

4.3.2 For metallic tubes, the length of the specimen is to be at least 1,5 times the external diameter of the tube except when a mandrel with an included angle of 30° is used, in which case the length of the specimen is to be twice the external diameter of the tube. In all cases the length of section remaining cylindrical after test is not be less than 0,5 times the external diameter.

4.3.3 Testing is to be carried out at ambient temperature and is to consist of expanding the end of the tube symmetrically by means of a hardened conical steel mandrel having a total included angle of 30°, 45° or 60°, *see* Fig. 2.4.1. The mandrel is to be forced into the test specimen at a rate not exceeding 50 mm/min until the percentage increase in the outside diameter of the end of the test specimen is not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The mandrel is to be lubricated, but there is to be no rotation of the tube or mandrel during the test. The expanded portion of the tube is to be free from cracks or other flaws.

4.4 Flanging tests

4.4.1 The test specimens are to be cut with the ends perpendicular to the axis of the tube. The length of the specimens is to be at least equal to the external diameter of the tube and such that after testing the portion that remains cylindrical is not less than half the external diameter. The edges of the end to be tested may be rounded by filing.

4.4.2 Testing is to be carried out at ambient temperature and is to consist of flanging the end of the tube symmetrically by means of hardened conical steel mandrels. The rate of flanging is not to exceed 50 mm/min.

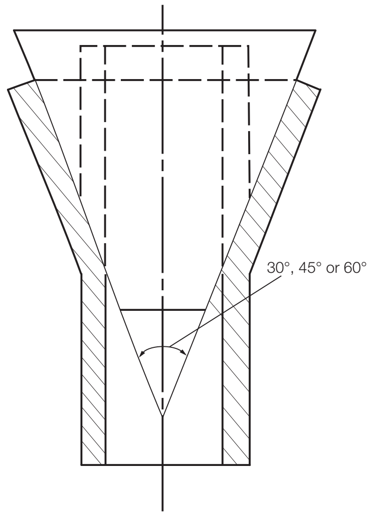


Fig. 2.4.1 Drift expanding test

4.4.3 The first stage of flanging is to be carried out with a conical angled mandrel having an included angle of approximately 90°, *see* Fig. 2.4.2(a). The completion of the test is achieved with a second forming tool as shown in Fig. 2.4.2(b). The mandrels are to be lubricated and there is to be no rotation of the tube or mandrels during the test. The test is to continue until the drifted portion has formed a flange perpendicular to the axis of the test specimens. The percentage increase in the external diameter of the end of the specimens is to be not less than the value given in the specific requirements for boiler and superheater tubes, *see* Chapter 6. The cylindrical and flanged portion of the tube is to be free from cracks or other flaws.

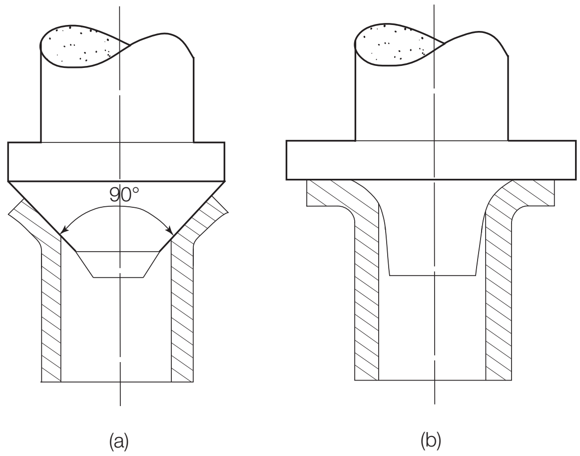


Fig. 2.4.2 Flanging test

Section 5
Embrittlement tests

5.1 Temper embrittlement tests

5.1.1 The test material is to be heat treated in accordance with the specification except that after tempering:
(a) half the material is to be water quenched;
(b) the other half is to be cooled from the tempering temperature to 300°C at a rate not exceeding 10°C per minute.

5.1.2 Impact tests in accordance with Section 3 are to be made on the material in each condition at temperatures over a range wide enough to establish the upper and lower shelf energies and temperatures, tests being made at no less than three intermediate temperatures.

5.1.3 A set of three specimens is to be tested at each temperature. The results are to be plotted separately for each condition, in the form illustrated in Fig. 2.5.1. In addition, the test temperatures, proportions of crystallinity and absorbed energies for all the specimens tested are to be reported.

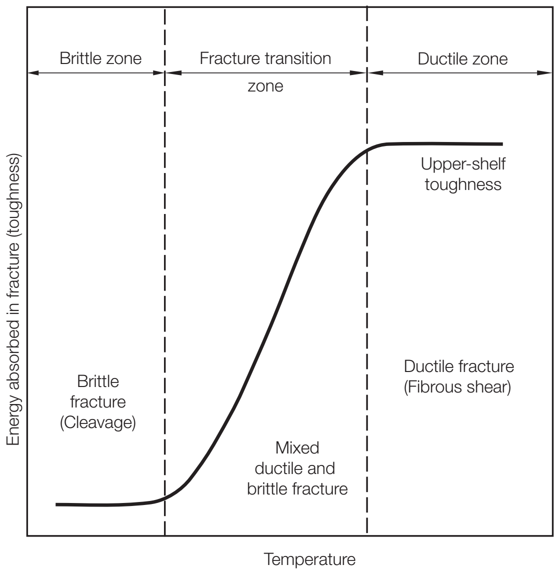


Fig. 2.5.1 Idealised transition curve

5.1.4 The transition temperature for each condition is to be taken as the mid-temperature of the fracture transition zone. The difference between the two transition temperatures is to be reported.

5.2 Strain age embrittlement tests

5.2.1 The test material is to be heat treated in accordance with the specification and then subjected to five per cent strain. Half of the test material is then to be heated to 250°C and held for one hour.

5.2.2 Impact tests in accordance with 5.1.2 are to be made in both the strained and unstrained conditions.

5.2.3 The tests are to comply with 5.1.3.

5.2.4 The test results are treated in accordance with 5.1.4.

5.3 Hydrogen embrittlement tests

5.3.1 Two specimens are to be tested. The specimens are to be of a diameter of 20 mm. Where this is not practicable a diameter of 14 mm may be accepted.

5.3.2 One specimen is to be tested within a maximum of 3 hours after machining. Where the specimen diameter is 14 mm, the time limit is 1,5 hours. Alternatively, the specimen may be cooled to –60°C immediately after machining and kept at that temperature for a maximum period of 5 days before being tested.

5.3.3 The other specimen is to be tested after baking at 250°C for 4 hours. Where the specimen diameter is 14 mm the baking time is to be 2 hours.

5.3.4 A strain rate not exceeding 0,0003s^{-1} is to be used during the entire test, until fracture occurs.

5.3.5 Tensile strength, elongation and reduction of area are to be reported.

5.3.6 The ratio Z_1/Z_2 is to be reported, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

Section 6
Crack tip opening displacement tests

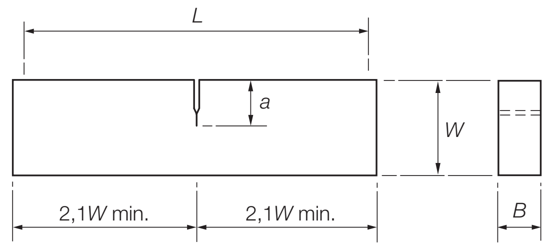
6.1 Dimensions of test specimens

6.1.1 Unless agreed otherwise, tests are to be made on specimens of the full section thickness and which conform to a nationally agreed standard.

6.1.2 Normally the specimens are to be rectangular with the main dimensions as indicated in Fig. 2.6.1 and are to be tested in three point bending.

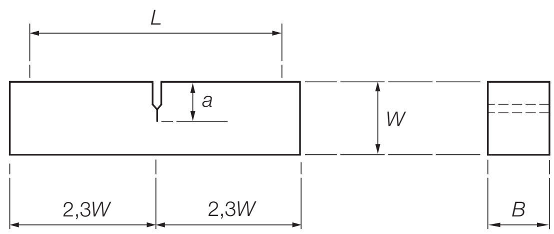
6.1.3 A subsidiary specimen as in Fig. 2.6.2 may be used by agreement.

6.1.4 In each case the notch is to be positioned at the centre of the loading span; its root radius is not to exceed 0,10 mm. The notch is to be extended by the generation of a fatigue crack to give an effective crack length of the dimension *a*. For this purpose, the fatigue stress ratio, R_1, is to be within the range 0 to 0,1 and the fatigue intensity is not to exceed $0{,}63\sigma_\gamma B^{1/2}$ where σ_γ is the 0,2 per cent proof stress at the test temperature.



B = thickness
W = width = $2B$
a = effective crack length = $0,45W$ to $0,55W$
L = loading span = $4W$

Fig. 2.6.1
Outline dimensions of the preferred specimen



B = thickness
W = width = B
a = effective crack length (to be agreed between the purchaser and manufacturer)
L = loading span = $4W$

Fig. 2.6.2
Outline dimensions of the subsidiary specimen

6.2 Test equipment

6.2.1 Whenever possible, tests are to be made using machines operating under displacement control. The type of control is to be recorded.

6.2.2 The test equipment is to be calibrated annually.

6.2.3 The crack opening displacement gauge is to have an accuracy of at least one per cent. It is to be calibrated at least once every day of testing and at intervals of no more than 10 tests. It should be demonstrated that the calibration is satisfactory for the test conditions.

6.3 Testing procedures

6.3.1 Tests are to be made in a recognised test house in accordance with a nationally accepted standard.

6.3.2 Unless otherwise agreed, all tests on unwelded wrought material are to be made on specimens taken transverse to the principal working direction and are to be through-thickness notched.

6.3.3 Where tests are made on weld material, the fatigue crack should be arranged to sample the maximum amount of unrefined weld metal.

6.3.4 Where tests are made on the Heat Affected Zone (H.A.Z.) of a weld, a K or single bevel weld preparation is recommended. The region of lowest fracture toughness in the Heat Affected Zone should be identified for the particular steel and weld procedure by means of preliminary tests. The fatigue crack is to be accurately positioned to sample as high a proportion of this critical region as possible and after testing has been completed, the specimen is to be sectioned to check that this has been achieved. Sufficient tests should be made to ensure that the critical region has been sampled in at least three specimens.

6.3.5 At least three valid tests are to be made for each material condition. Invalid tests are to be disregarded and the tests repeated.

6.3.6 Local pre-compression of the test specimen ahead of the notch is acceptable in order to provide an acceptably even fatigue crack front.

6.3.7 The temperature of the test piece is to be measured to within ±2°C over the range minus 196°C to +200°C and to within ±5°C outside this range. The temperature should be measured at a point on the specimen not farther than 2 mm away from the crack tip.

6.4 Validity requirements

6.4.1 The test is to be regarded as invalid if:
(a) the fatigue crack front is not in a single plane;
(b) any part of the fatigue crack surface lies in a plane whose angle with the plane of the notch exceeds 10°;
(c) the length of any part of the fatigue crack is less than $0,025W$ or 1,25 mm, whichever is the greater;
(d) the difference between the maximum and minimum lengths of the fatigue crack exceeds $0,1W$;
(e) the difference between any two of the lengths of the fatigue crack at $0,25B$, $0,5B$ and $0,75B$ exceeds $0,05W$.

6.4.2 In addition, for tests on welds and Heat Affected Zones (H.A.Z.), the following criteria are to be complied with:
(a) Weld metal. The fatigue crack front shall not extend outside the weld metal deposit and 80 per cent should be within 2 mm of the fusion line.
(b) Grain coarsened H.A.Z The fatigue crack should be within 0,5 mm of the fusion line and should sample all of the grain coarsened H.A.Z present. However, if fusion line irregularities prevent this, a sample including as much grain coarsened H.A.Z as possible may be accepted.
(c) Subcritical/intercritical H.A.Z boundary. The fatigue crack is to sample the boundary between the subcritical and intercritical regions of the H.A.Z However, if fusion line irregularities prevent this, a sample including as much relevant microstructure as possible may be accepted.

6.5 Test reports

6.5.1 The test report is to include:
(a) details of the material, its condition and size;
(b) the thickness and width of the test specimen;
(c) the fatigue pre-cracking conditions;
(d) the test temperature and environment;
(e) the test machine control system and rate of change of displacement or load;
(f) crack length measurements;
(g) force/displacement records, preferably in the form of an autographic record;
(h) the critical crack opening displacement;
(j) a photograph of the fracture;
(k) any observation on the fracture surface.

Section 7
Bend tests

7.1 Dimensions of test specimens

7.1.1 Flat bend test specimens are to be of rectangular cross-section with dimensions as defined in Fig. 2.7.1.

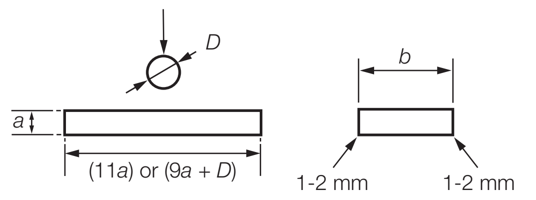


Fig. 2.7.1 Bend test specimen

7.1.2 For plates, sections and strip the dimensions shall be full thickness and width 30 mm. Where the rolled thickness exceeds 25 mm the compression face may be reduced to 25 mm.

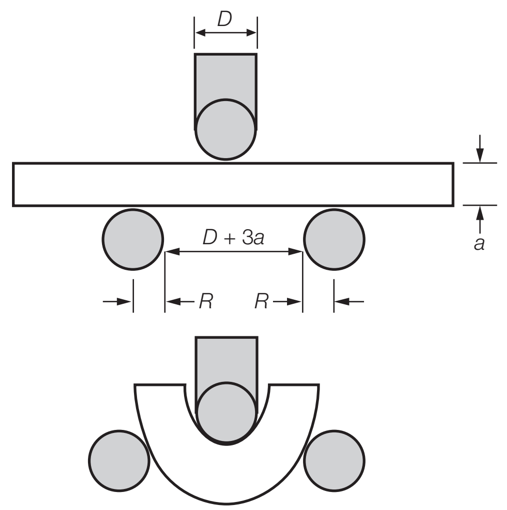
7.1.3 For forgings, castings and semi-finished products the thickness shall be 20 mm and width 25 mm.

7.1.4 Butt weld face and root bend test specimens are to be 30 mm in width and of the full plate thickness. Where the thickness exceeds 25 mm, two side bend test specimens may be tested in place of the face and root specimens specified. The side bend specimens should be 10 mm minimum thickness. The upper and lower surfaces of the weld are to be filed, ground or machined flush with the surface of the plate.

7.1.5 The edges on the tension side of bend samples are to be rounded to a radius of 1 to 2 mm.

7.2 Testing procedures

7.2.1 The bend sample is plastically deformed by plunging a mandrel between two fixed points as shown in Fig. 2.7.2.



a = thickness of bend sample
R = radius of roller
D = outside diameter of former

Fig. 2.7.2 Bend test

7.2.2 For aluminium welds a guided bend is required to ensure even deformation as shown in Fig. 2.7.3.

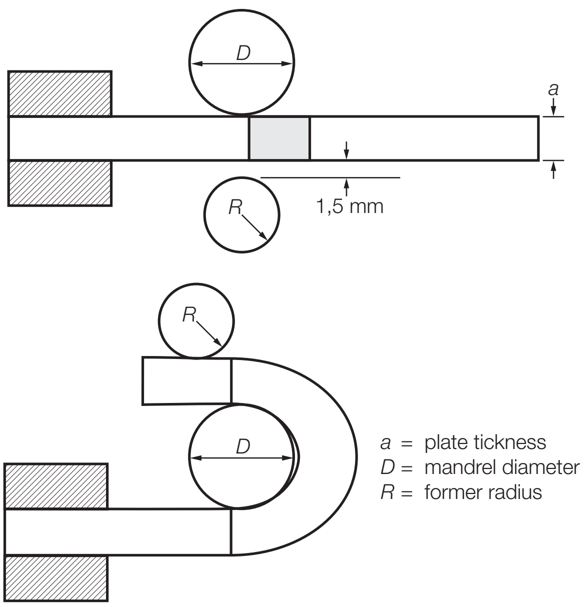


Fig. 2.7.3 Guide bend test for aluminium

7.2.3 Bend tests are to be conducted at ambient temperature at the highest convenient rate of bending (but not impact).

Section 8
Corrosion tests

8.1 Intergranular corrosion test

8.1.1 For all products other than pipes, the material for the test specimens is to be taken adjacent to that for the tensile test and is to be machined to suitable dimensions for either a round or rectangular section bend test. The diameter or thickness is to be not more than 12 mm, and the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases the total surface area is to be between 1500 mm^2 and 3500 mm^2.

8.1.3 Specimens are to be heated to a temperature of 700 ± 10ºC for 30 minutes, followed by rapid cooling in water. They are then to be placed on a bed of copper turnings (50 g per litre of test solution) and immersed for 15 to 24 hours in a boiling solution of the following composition:

- 100 g of hydrated copper sulphate granules ($CuSO_4 . 5H_2O$)
- 184 g (100 ml) sulphuric acid (density 1,84 g/ml) added dropwise to distilled water to make 1 litre of solution.

Precautions are to be taken during boiling to prevent concentration of the solution by evaporation.

8.1.4 After immersion, the full cross-section test specimens from pipes are to be subjected to a flattening test in accordance with Ch 2,4.2. All other test specimens are to be bent, at ambient temperature, through 90º over a former with a diameter equal to twice the diameter or thickness of the test specimen.

8.1.5 After flattening or bending, the test specimens are to be free from cracks on the outer, convex surface.

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for hot rolled plates and sections intended for use in the construction of ships, other marine structures, machinery, boilers and pressure vessels.

1.1.2 This Chapter is not applicable to hot rolled bars intended for the manufacture of bolts, plain shafts, etc., by machining operations only. Where used for this purpose, hot rolled bars are to comply with the requirements of Chapter 5.

1.1.3 Plate and strip which is hot coiled after rolling and subsequently uncoiled, cold flattened and cut to the required dimensions are also subject to the appropriate requirements of this Chapter.

1.1.4 Plates, strip, sections and bars are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2 to 10.

1.1.5 As an alternative to 1.1.4, materials which comply with National or proprietary specifications may be accepted, provided that these specifications give equivalence to the requirements of this Chapter or are approved for a specific application. Particular attention is to be taken of the minimum required under thickness tolerance, *see* 1.5. Generally, survey and certification of such materials are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 Steels intended for high heat input welding above 50 kJ/cm are to be specially approved. Approval will be indicated on the manufacturer's approval certificate by adding a high heat input welding notation to the grade approved e.g., EH36-W300, indicating approval up to 300 kJ/cm.

1.2 Steel with guaranteed through thickness properties – 'Z' grade steel

1.2.1 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, 'Z' grade steel. These strains are usually associated with thermal contraction and restraint during welding, particularly for full penetration 'T'-butt welds, but may also be associated with loads applied in service or during construction. Where these strains are of sufficient magnitude, lamellar tearing may occur. Requirements for 'Z' grade plate material are detailed in Section 8. It is the responsibility of the fabricator to make provision for the use of this material.

1.2.2 Steels intended to have guaranteed through thickness properties will include the supplementary suffix Z25 or Z35 in the designation, for example: LR DH36 Z35.

1.3 Manufacture

1.3.1 All materials are to be manufactured at works which have been approved by LR for the type and grade of steel which is being supplied and for the relevant steelmaking and processing route.

1.3.2 Steel is to be cast in metal ingot moulds or by the continuous casting process. The size of the ingot, billet or slab is to be proportional to the dimensions of the final product such that the reduction ratio is normally to be at least 3 to 1. Sufficient discard is to be taken to ensure soundness in the portion used for further processing.

1.3.3 The cast analysis to be used for certification purposes is to be determined after all alloying additions have been carried out and sufficient time allowed for such an addition to homogenise.

1.3.4 Material may be supplied either as-rolled, normalised, normalising rolled, or thermomechanically controlled rolled. The following definitions apply:

(a) As-rolled (AR) refers to rolling of steel at high temperature followed by air cooling. The rolling and finishing temperatures are typically in the austenite recrystallisation region and above the normalising temperature. The strength and toughness properties of steel produced by this process are generally less than those of steel heat treated, after rolling, or steel produced by advanced processes.

(b) Normalising (N) refers to an additional heating cycle of rolled steel above the critical temperature, A_{c3}, and in the lower end of the austenite recrystallisation region followed by air cooling. The process improves the mechanical properties of as-rolled steel by refining the grain size.

(c) Normalising rolling (NR), also known as controlled rolling, is a rolling procedure in which the final deformation is carried out in the normalising temperature range, resulting in a material condition generally equivalent to that obtained by normalising.

(d) Thermomechanically controlled rolling (TM) is a procedure which involves the strict control of both the steel temperature and the rolling reduction. Generally a high proportion of the rolling reduction is carried out close to the A_{r3} temperature and may involve the rolling in the dual phase temperature region. Unlike normalising rolling the properties conferred by TM (TMCP) cannot be reproduced by subsequent normalising or other heat treatment. The use of accelerated cooling on completion of TM may also be accepted subject to the special approval by LR.

(e) Accelerated Cooling, (AcC) is a process which aims to improve mechanical properties by controlled cooling with rates higher than air cooling immediately after the final TM operation. Direct quenching is excluded from accelerated cooling. The material properties conferred by TM and AcC cannot be reproduced by subsequent normalising or other austenitising heat treatment.

(f) Quenching and Tempering (QT),is a heat treatment process in which steel is heated to an appropriate temperature above the A_{c3} and then cooled with an appropriate coolant for the purpose of hardening the microstructure, followed by tempering, a process in which the steel is re-heated to an appropriate temperature, not higher than the A_{c1} to restore the toughness properties by improving the microstructure.

1.3.5 Where material is being produced by a normalising rolling or a thermomechanically controlled process (T.M.) an additional program of tests for approval is to be carried out under the supervision of the Surveyors and the results are to be to the satisfaction of Lloyd's Register (hereinafter referred to as 'LR').

1.3.6 Weldable high strength steels may be supplied in the quenched and tempered condition for other marine structures, *see* Section 10.

1.4 Quality of materials

1.4.1 Surface and internal imperfections not prejudicial to the proper application of the steel are not, except by special agreement, to be grounds for rejection. Where necessary, suitable methods of non-destructive examination may be used for the detection of harmful surface and internal defects. The extent of this examination, together with an appropriate acceptance standard, is to be agreed between the purchaser, steelmaker and Surveyor and is to be included in the manufacturing specification.

1.5 Dimensional tolerances

1.5.1 The tolerances on thickness of a given product are defined as:

(a) Minus tolerance is the lower limit of the acceptable range below the nominal thickness.

(b) Plus tolerance is the upper limit of the acceptable range above the nominal thickness.

Nominal thickness is defined by the purchaser at the time of enquiry and order.

1.5.2 The average thickness of a product or products is defined as the arithmetic mean of the measurements made in accordance with the requirements in 1.5.10.

1.5.3 For materials of nominal thickness 5 mm and more intended for hull structural purposes as detailed in Sections 2, 3 and 10, the minus tolerance on thickness of plates, strip and wide flats is 0,3 mm, irrespective of nominal thickness. For wide flats, this applies only where the width is greater than or equal to 600 mm. The average thickness of a product or products is not to be less than the nominal thickness. For thickness below 5 mm, the thickness tolerances are to be specially agreed.

1.5.4 Class C of ISO 7452 may be applied in lieu of 1.5.3. Where this standard is applied, both the requirements in 1.5.11 and the portion of the footnote of Table B.2 in ISO 7542, that reads; "Also a minus side of thickness of 0,3 mm is permitted," are not applicable. Additionally, if ISO 7452 is applied, the steel mill is to ensure that the number of measurements and measurement distribution is appropriate to establish that the plates produced are greater than or equal to the specified nominal thickness.

1.5.5 The minus tolerance on bars and sections (except for wide flats with a width $\geq$ 600 mm) is to be in accordance with the requirements of a recognised National or International Standard.

1.5.6 The Shipbuilder and Owner may agree in individual cases whether they wish to specify a more stringent minus tolerance than that given in this Chapter.

1.5.7 The minus tolerances for plates and wide flats intended for machinery structures are given in Section 5.

1.5.8 For materials intended for applications as detailed in Sections 4 and 6, no minus tolerance is permitted in the thickness of plates and strip. The minus tolerances on sections are to comply with the requirements of a recognised National or International Standard.

1.5.9 For the materials detailed in Section 7, the minus tolerance of material intended for use in the construction of cargo tanks is not to exceed 0,3 mm. For other applications, no minus tolerance is permitted in the thickness of plates and strip.

1.5.10 Dimensional tolerances for material detailed in Section 9 are given in Table 3.9.3.

1.5.11 The average thickness and thickness tolerance is to be measured at locations of a product or products as defined below:

(a) An automated method or manual method may be applied to the thickness measurements. The procedure and the records of measurements are to be made available to the Surveyor and copies provided on request.

(b) At least two lines among Line 1, Line 2 or Line 3, as shown in Fig. 3.1.1, are to be selected for the thickness measurements and at least three points on each selected line as shown in Fig. 3.1.1 are to be selected for thickness measurement. If more than three points are taken on each line, then the number of points shall be equal on each line.

(c) For automated methods, the measuring points at sides are to be located not less than 10 mm but not greater than 300 mm from the transverse or longitudinal edges of the product.

(d) For manual methods, the measuring points at sides are to be located not less than 10 mm but not greater than 100 mm from the transverse or longitudinal edges of the product.

(e) Additional measurements may be requested by the Surveyor.

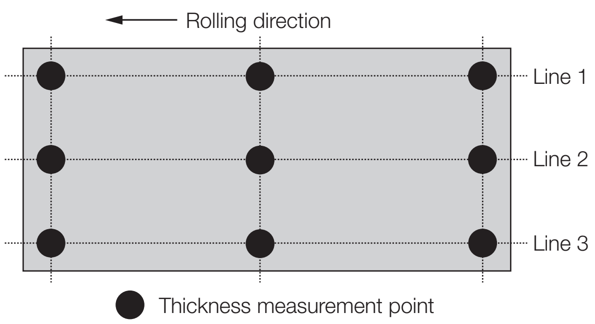


Fig. 3.1.1 Location of thickness measuring points

1.5.12 Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a recognised National or International Standard.

1.5.13 Tolerances relating to length, width, flatness and plus thickness are to comply with a National or International Standard.

1.5.14 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

1.5.15 The Shipbuilder is responsible for the storage and maintenance of product(s) delivered with acceptable surface conditions.

1.6 Heat treatment

1.6.1 Acceptable conditions of supply are specified in subsequent Sections of this Chapter.

1.6.2 The manufacturer is to carry out any heat treatment which may be necessary to prevent hydrogen cracking or to make the material in a safe condition for transit. The Surveyor is to be advised of any heat treatment proposed.

1.6.3 Where material is manufactured using a thermo-mechanically controlled process consideration must be given to the possibility of consequent reduction in mechanical properties if it is subjected to heating for forming or stress relieving or is welded using a high heat input.

1.7 Test material and mechanical tests

1.7.1 Depending on the type of product, provision is made in subsequent Sections of this Chapter for the testing of individual items or for batch testing. Where the latter is permitted, all materials in a batch presented for acceptance tests are to be of the same product form, (e.g., plates, flats, sections, etc.), from the same cast and in the same condition of supply.

1.7.2 The test samples are to be fully representative of the material and, where appropriate, are not to be cut from the material until heat treatment has been completed. The test specimens are not to be separately heat treated in any way.

1.7.3 The test material is to be taken from the thickest piece in each batch, *see* Ch 1,4.1.

1.7.4 Test material is to be taken from the following positions:

(a) At the square cut end of plates and flats greater than 600 mm wide, approximately one-quarter width from an edge, *see* Fig. 3.1.2(a).

(b) For flats 600 mm or less in width, bulb flats and other solid sections, at approximately one-third of the width from an edge, *see* Fig. 3.1.2(b), (c) and (d). Alternatively, in the case of channels, beams or bulb angles, at approximately one-quarter of the width from the centreline of the web, *see* Fig. 3.1.2(c).

(c) For rectangular hollow sections, at approximately the centre of any side, *see* Fig. 3.1.2(e). For circular hollow sections, at any position on the periphery.

(d) For bars intended for purposes as detailed in Sections 2, 3, 5 and 9, at approximately one-third of the radius or half-diagonal from the outer surface, *see* Fig. 3.1.2(f). For smaller bars, the position of the test material is to be as close as is possible to the above.

(e) For bars intended for the applications detailed in Sections 4, 6 and 7 at approximately 12,5 mm below the surface. For bars up to 25 mm diameter, the test specimens may be machined coaxially.

(f) For plates and flats with thicknesses in excess of 40 mm, full thickness specimens may be prepared, but when instead a machined round specimen is used then the axis is to be located at a position lying one-quarter of the product thickness from the surface as shown in Fig. 3.1.2(g).

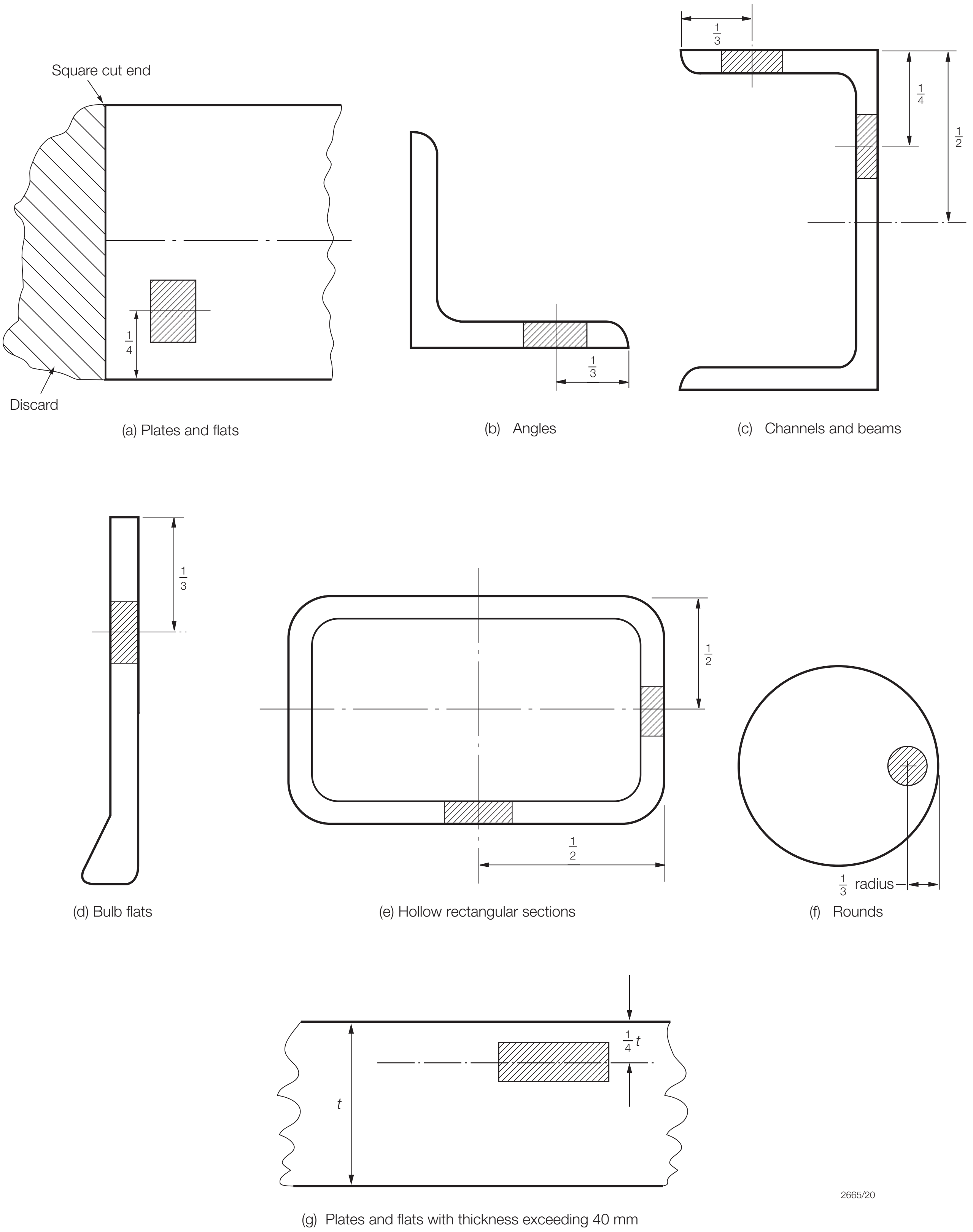


Fig. 3.1.2 Position of test material

1.7.5 Tensile test specimens and impact test specimens, where required for the type and grade of product being supplied, are to be prepared from each item or batch of material submitted for acceptance.

1.7.6 Where the finished width of plates and flats is greater than 600 mm, the tensile test specimens are to be cut with their principal axes perpendicular to the final direction of rolling. For all other rolled products, the principal axes are to be parallel to the final direction of rolling.

1.7.7 The tensile test specimens are to be machined to the dimensions detailed in Ch 2,2.1.6 and 2.1.7.

1.7.8 Impact test specimens are to be cut with their principal axes either parallel (longitudinal test) or perpendicular (transverse test) to the final direction of rolling, as required by subsequent Sections of this Chapter. Where both longitudinal and transverse impact properties are shown for a particular grade, only the longitudinal test is required to be carried out, unless otherwise specified by the purchase order or subsequent Sections of this Chapter. However, for plates and wide flats, by certifying that the product meets the requirements of the Rules, the manufacturer guarantees that the acceptance values will be met if tested in the transverse direction. The Surveyor may request testing in this direction to confirm conformity.

1.7.9 Impact test specimens are to be of the Charpy V-notch type, machined to the dimensions detailed in Chapter 2. They are to be taken from a position within 2 mm of one of the rolled surfaces, except that for plates and sections over 40 mm thick, the axes of the test specimens are to be at one-quarter of the thickness from one of the rolled surfaces. For bars and other similar products the axes of the test specimens are to be as specified in 1.7.4(d).

1.7.10 Standard test specimens 10 mm square are to be used, except where the thickness of the material does not allow this size of test specimen to be prepared. In such cases the largest possible size of subsidiary test specimen, in accordance with Table 2.3.1 is to be prepared, with the notch cut on the narrow face. Alternatively, for material of suitable thickness, the rolled surfaces may be retained so that the test specimen width will be the full thickness of the material. In such cases the tolerances for width given in Table 2.3.1 in Chapter 2 are not applicable. The notch is to be cut in a face of the test specimen which was originally perpendicular to the rolled surface. The position of the notch is to be not nearer than 25 mm to a flame-cut or sheared edge.

1.7.11 Impact tests are not required when the nominal material thickness is less than 6 mm.

1.7.12 The test procedures used for all tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.8 Visual and non-destructive examination

1.8.1 Surface inspection and verification of dimensions are the responsibility of the steelmaker and are to be carried out on all material prior to despatch. Acceptance by the Surveyors of material later found to be defective shall not absolve the steelmaker from this responsibility.

1.8.2 With the exception of 'Z' grade plate material (*see* Section 8) and bars for offshore mooring cable (*see* Section 9), the non-destructive examination of materials is not required for acceptance purposes, *see also* 1.4.1. However, manufacturers are expected to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.9 Rectification of defects

1.9.1 For materials intended for structural purposes as detailed in Sections 2, 3 and 5, surface defects may be removed by local grinding provided that:

(a) the thickness is in no place reduced to less than 93 per cent of the nominal thickness, but in no case by more than 3 mm,
(b) each single ground area does not exceed 0,25 m^2,
(c) the total area of local grinding does not exceed two per cent of the total surface,
(d) the ground areas have smooth transitions to the surrounding surface.

Where necessary, the entire surface may be ground to a maximum depth as given by the underthickness tolerances of the product. The extent of such rectification is to be agreed in each case with the Surveyors and is to be carried out under their supervision, unless otherwise agreed. They may request that complete removal of the defect is proven by suitable non-destructive examination of the affected area.

1.9.2 Surface defects which cannot be dealt with as in 1.9.1 may be repaired by chipping or grinding followed by welding, subject to the Surveyor's consent and under his supervision, provided that:

(a) after removal of the defect and before welding, the thickness of the item is in no place reduced by more than 20 per cent,
(b) each single weld does not exceed 0,125 m^2,
(c) the total area of welding does not exceed two per cent of the surface of the side involved,
(d) the distance between any two welds is not less than their average width,
(e) the welds are of reasonable size and made with an excess layer of beads which is then ground smooth to the surface level,
(f) elimination of the defect is proven by suitable non-destructive examination of the affected area,
(g) welding is carried out by an approved procedure and by competent operators using approved electrodes and the repaired area is ground smooth to the correct nominal thickness,
(h) when requested by the Surveyor, the item is normalised or otherwise suitably heat treated after welding and grinding, and
(j) at the discretion of the Surveyor, the repaired area is proven free from defects by suitable non-destructive examination.

1.9.3 For materials intended for applications as detailed in Sections 4, 6 and 7, surface defects may be removed by grinding in accordance with 1.9.1, except that when the thickness is reduced below that given in the approved plans, acceptance will be subject to special consideration. Weld repairs may also be carried out generally in accordance with 1.9.2, except that in all cases suitable heat treatment after welding and non-destructive testing of the repaired areas is required. The fabricator is to be advised regarding the position and extent of all repairs.

1.9.4 For plates which have been produced by a T.M. process or by normalising rolling, repair by welding will be approved by the Surveyor only after procedure tests have shown that the mechanical properties have not been impaired.

1.9.5 Cracks, shells, sand patches and sharp edged seams are always considered defects which would impair the end use of the product and which require rejection or repair irrespective of their size and number. The same applies to other imperfections exceeding the acceptable limits.

1.10 Identification of materials

1.10.1 Every finished item is to be clearly marked by the manufacturer in at least one place with LR's brand ℞ and the following particulars:

(a) The manufacturer's name or trade mark.
(b) The grade of steel. The designations given in subsequent Sections of this Chapter may be preceded by the letters 'LR' in order to fully describe the grade, e.g. LR A, LR 490FG. LR LT-FH40, LR 316L, etc.
(c) When the material complies with the requirements of Section 8, the grade is to include the suffix Z25 or Z35, e.g., LR AH36 Z35.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) If required by the purchaser, his order number or other identification mark.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

1.10.2 Where a number of light materials are securely fastened together in bundles, the manufacturer may brand only the top piece of each bundle or, alternatively, a firmly fastened durable label containing the identification may be attached to each bundle.

1.10.3 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be unmistakably defaced, *see also* Ch 1,4.8.

1.11 Certification of materials

1.11.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1) and is to include the following particulars:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is dispatched.
(d) Name of steelworks.
(e) Description and dimensions of the material.
(f) Specification or grade of the steel.
(g) Identification number of piece, including test specimen number where appropriate.
(h) Cast number and chemical composition of ladle samples.
(j) Mechanical test results (not required on shipping statements).
(k) Condition of supply.

1.11.2 Before the test certificates are signed by the Surveyor, the steelmaker is required to provide a written declaration stating that the material has been made by an approved process, and that it has been subjected to and has withstood satisfactorily the required tests in the presence of the Surveyor, or an authorised deputy. The following form of declaration will be accepted if stamped or printed on each test certificate with the name of the steelworks and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved process and satisfactorily tested in accordance with the Rules of Lloyd's Register'.

1.11.3 When steel is not produced at the works at which it is rolled, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the chemical composition of ladle samples. The works at which the steel was produced must be approved by LR.

1.11.4 The manufacturer of coiled plate is required to issue a certificate which clearly identifies the material as coil. The certificate issued should include the words; 'Coils covered by this certificate require further processing at a works approved by Lloyd's Register before being certified as plate in accordance with the Rules of Lloyd's Register' in addition to the requirements of 1.11.2.

1.11.5 The supplier of plate cut from coil is required to issue a certificate which clearly identifies the product as finished plate meeting the requirements of the Rules in accordance with 1.11.2.

1.11.6 The form of certificates produced by computer systems is to be agreed with the Surveyor.

■ *Section 2*
Normal strength steels for ship and other structural applications

2.1 Scope

2.1.1 The requirements of this Section are primarily intended to apply to steel plates and wide flats not exceeding 100 mm in thickness and sections and bars not exceeding 50 mm in thickness in Grades A, B, D and E. For greater thicknesses, variations in the requirements may be permitted or required for particular applications.

Table 3.2.1 Chemical composition and deoxidation practice

Grade	A	B	D	E
Deoxidation	For $t \leq 50$ mm: Any method (for rimmed steel, *see* Note 1)	For $t \leq 50$ mm: Any method except rimmed steel	For $t \leq 25$ mm: Killed	Killed and fine grain treated with aluminium
	For $t > 50$ mm: Killed	For $t > 50$ mm: Killed	For $t > 25$ mm: Killed and fine grain treated with aluminium	
Chemical composition % (*see* Note 5)				
Carbon	0,21 max. (*see* Note 2)	0,21 max.	0,21 max.	0,18 max.
Manganese	2,5 x C% min.	0,80 min. (*see* Note 3)	0,60 min.	0,70 min.
Silicon	0,50 max.	0,35 max.	0,10 – 0,35	0,10 – 0,35
Sulphur	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Phosphorus	0,035 max.	0,035 max.	0,035 max.	0,035 max.
Aluminium (acid soluble)	—	—	0,015 min. (*see* Note 4)	0,015 min. (*see* Note 4)
	Carbon + $^{1}/_{6}$ of the manganese content is not to exceed 0,40%			

NOTES
1. For Grade A, rimmed steel may only be accepted for sections up to a maximum thickness of 12,5 mm, provided that it is stated on the test certificates or shipping statements to be rimmed steel.
2. The maximum carbon content for Grade A steel may be increased to 0,23% for sections.
3. Where Grade B is impact tested the minimum manganese content may be reduced to 0,60%.
4. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
5. Where additions of any other elements are made as part of the steelmaking practice, the content is to be recorded.

2.1.2 Additional approval tests may be required to verify the suitability for forming and welding of Grade E plate exceeding 50 mm in thickness.

2.2 Manufacture and chemical composition

2.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 3.2.1.

2.2.2 Small variations from the chemical compositions given in Table 3.2.1 may be allowed for Grade E steel in thicknesses exceeding 50 mm or when any Grade of steel is supplied in a thermo-mechanically controlled processed condition, provided that these variations are documented and approved in advance.

2.2.3 The manufacturer's declared analysis will be accepted subject to occasional checks if required by the Surveyors.

2.2.4 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

2.3 Condition of supply

2.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.2.2. Where alternative conditions are permitted these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material, but a steelmaker is to supply materials only in those conditions for which he has been approved by LR.

2.3.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

2.3.3 If a steel product supplied in the T.M. condition is to be subjected to heating for forming or stress relieving or is to be welded by a high energy input process, consideration must be given to the possibility of a consequent reduction in mechanical properties.

2.4 Mechanical tests

2.4.1 The results of all tensile tests and the average energy value from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3 except where enhanced by the requirements of this Section.

Table 3.2.2 Condition of supply

Grade	Thickness, mm	Conditions of supply			
A and B	≤50	Any			(*see* Note 1)
	>50 ≤100	N	NR	TM	(*see* Note 2)
D	≤35	Any			(*see* Note 1)
	>35 ≤100	N	NR	TM	(*see* Note 3)
E	≤100	N		TM	(*see* Note 4)

N = normalised
NR = normalising rolled
TM = thermomechanically controlled-rolled

NOTES
1. 'Any' includes as-rolled, normalised, normalising rolled and thermomechanically controlled-rolled.
2. Plates, wide flats, sections and bars may be supplied in the as-rolled condition, subject to special approval from LR.
3. Sections in Grade D steel may be supplied in thicknesses greater than 35 mm in the as-rolled condition provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Sections in Grade E steel may be supplied in the as-rolled and normalising rolled conditions provided that satisfactory results are consistently obtained from Charpy V-notch impact tests.

2.4.2 With the exception given in 2.4.4, one tensile test is to be made for each batch presented unless the mass of finished material is greater than 50 tonnes, in which case one test is to be made from a different piece from each 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast. For sections, the thickness to be considered is the thickness of the product at the point at which samples are taken for mechanical tests. A piece is to be regarded as the rolled product from a single slab or billet, or from a single ingot if this is rolled directly into plates, strip, sections or bars.

2.4.3 For Grades A and B where plate is supplied from coil, results of the tensile test can be transposed from the certificate of the coil manufacture onto the certificate issued by the re-processor. If the coil mass exceeds 50 tonnes, testing will additionally be required from two locations representing the start and end of the coil. For Grades D and E, the mechanical properties must be sampled from the de-coiled plate in accordance with the frequency specified in the Rules.

2.4.4 For plates of thickness exceeding 50 mm in Grade E steel, one tensile test is to be made on each piece.

Table 3.2.3 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Charpy V-notch impact test (*see* Notes 3, 4, 5, 6 and 7)		
				Thickness mm	Average energy J minimum	
					Longitudinal	Transverse (*see* Note 3)
A B D E	235	400 – 520 (*see* Note 1)	22 (*see* Note 2)	≤50 >50 ≤70 >70 ≤100	27 34 41	20 24 27

Impact tests are to be made on the various grades at the following temperatures:
A grade not required
B grade 0°C
D grade –20°C
E grade –40°C

NOTES
1. For sections in Grade A, the upper limit of the tensile strength range may be exceeded at the discretion of the Surveyor.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2), the minimum elongation is to be:

Thickness mm	≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤35	>35 ≤50
Elongation %	14	16	17	18	19	20	21	22

3. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be garenteed by the supplier.
4. *See* 2.4.5 and 2.4.6.
5. *See* 2.4.7.
6. *See* 1.7.11.
7. *See* 2.4.14.

2.4.5 For Grade A steel, Charpy V-notch impact tests are not required when the thickness does not exceed 50 mm, or up to 100 mm thick if the material is supplied in either the normalised or thermo-mechanically controlled-rolled condition and has been fine grain treated. However, the manufacturer should confirm, by way of regular in-house checks, that the material will meet a requirement of 27 J at +20°C. The results of these checks shall be reported to the Surveyor. The frequency of these checks should as a minimum be every 250 tonnes.

2.4.6 When Grade A steel is supplied in a thickness greater than 50 mm and either, in the normalising rolled condition, or when special approval has been given to supply in the as-rolled condition, a set of three impact test specimens is to be tested from each batch of 50 tonnes or fraction thereof.

2.4.7 Impact tests are not required for Grade B steel of 25 mm or less in thickness. However, the manufacturer is to confirm, by way of regular in-house tests, and on occasional material selected by the Surveyor, that the material meets the requirement in Table 3.2.3. The results of the tests are to be reported to the Surveyor. The frequency of the in-house checks are to be, as a minimum, one set of three impact test specimens for every 250 tonnes.

2.4.8 For Grade B steels of thicknesses above 25 mm, supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.9 For Grade B steels of thicknesses above 25 mm, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.10 For Grade D steels supplied in the as-rolled or normalising rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 25 tonnes, one extra set of tests is to be made from a different piece from each 25 tonnes or fraction thereof.

2.4.11 For Grade D steels, supplied in the furnace normalised or thermomechanically controlled-rolled condition, one set of three impact test specimens is to be made from the thickest item in each batch presented. If the mass of finished material is greater than 50 tonnes, one extra set of tests is to be made from a different piece from each 50 tonnes or fraction thereof.

2.4.12 For plates in Grade E steel, one set of three impact test specimens is to be made from each piece. For bars and sections in Grade E steel, one set of three test specimens is to be made from each 25 tonnes or fraction thereof. When, subject to the special approval of LR, sections are supplied in the as-rolled or normalising rolled conditions, one set of impact tests is to be taken from each batch of 15 tonnes or fraction thereof.

2.4.13 The results of all tensile tests and the average energy values from each set of three impact tests are to comply with the appropriate requirements given in Table 3.2.3. For impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

2.4.14 For batch tested Grade B and D steel plates supplied in a condition other than furnace normalised, with a thickness equal to, or greater than 25 mm and 12 mm respectively, and where the average value of one set of tests is less than 40 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 40 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.2.3. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 2.3.2.

2.4.15 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

2.5 Identification of materials

2.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted. Where a number of light materials are bundled, the bundle is to be identified in accordance with 1.10.2.

2.6 Certification of materials

2.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to indicate if sections in Grade A steel of rimming quality have been supplied. As a minimum, the chemical composition is to include the contents of any grain refining elements used and the residual elements, as detailed in Table 3.2.1.

■ *Section 3*
Higher strength steels for ship and other structural applications

3.1 Scope

3.1.1 Provision is made for material to be supplied in four strength levels, 27S, 32, 36 and 40.

3.1.2 Provisions for material supplied in H47 strength grades are specifically intended for hatch comings and deck structure of container ships.

3.1.3 The required notch toughness is designated by subdividing the strength levels into Grades AH, DH, EH and FH.

3.1.4 For the designation to fully identify a steel and its properties the appropriate grade letters should precede the strength level number, e.g. AH32 or FH40.

3.1.5 The requirements of this Section are primarily intended to apply to plates, wide flats, sections and bars not exceeding the thickness limits given in Table 3.3.1. For greater thicknesses, variations in the requirements may be permitted or required for particular applications but a reduction of the required impact energy is not allowed.

3.1.6 It should be noted that the fatigue strength of weldments in steels of high strength levels may not be greater than those of steels of lower strength levels.

3.2 Alternative specifications

3.2.1 Steels differing from the requirements of this Section in respect of chemical composition, deoxidation practice, condition of supply or mechanical properties may be accepted subject to special approval by LR. Such steels are to be given a special designation, *see* 3.7.2.

3.3 Manufacture

3.3.1 All the grades of steel are to be in the killed and fine grain treated condition.

Table 3.3.1 Maximum thickness limits

Steel designation				Maximum thickness mm	
				Plates and wide flats	Sections and bars
AH 27S	DH 27S	EH 27S	FH27S	100 (see Note 1)	50
AH 32	DH 32	EH 32	FH32		
AH 36	DH 36	EH 36	FH36		
AH 40	DH 40	EH40	FH40		
AH 47 (*see* Note 2)	DH 47	EH 47	FH 47		Not applicable

NOTES
1. Where the thickness exceeds 50 mm, the steel must initially be approved by way of a Nil Ductility Test, in accordance with ASTM E208, to show adequate crack arrest properties. The Nil Ductility Test Temperature is to be agreed for the thickness approved to ensure the crack arrest temperature is below the minimum design temperature. Where the thickness exceeds 70 mm and the material is used specifically as a crack arrest plate, the material must be specially approved with a crack arrest fracture toughness Kca ≥ 6000 $N/mm^{1,5}$.
2. Minimum thickness for H47 strength level is 50 mm, *see* 3.1.2.

3.4 Chemical composition

3.4.1 The chemical compositions of ladle samples for all grades of steel are to comply with the requirements given in Table 3.3.2. The requirements for H47 strength grade steels are given in Table 3.3.3.

3.4.2 The carbon equivalent is to be calculated from the ladle analysis using the formula given below and is not to exceed the maximum value agreed between the fabricator and the steelmaker when the steel is ordered.

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$$

For TM steels, the agreed carbon equivalent is not to exceed the values given in Table 3.3.4.

3.4.3 The cold cracking susceptibility, P_{cm}, may be used instead of the carbon equivalent for evaluating weldability, in which case the following formula is to be used for calculating the P_{cm} from the ladle analysis:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the manufacturing specification and reported on the certificate.

3.4.4 The cold cracking susceptibility, P_{cm}, is to have a maximum value of 0,22 per cent for steels of H47 strength grade.

3.4.5 Small deviations in chemical composition from that given in Table 3.3.2 for plates exceeding 50 mm in thickness in Grades EH36, EH40, FH36 and FH40 may be approved provided that these deviations are documented and approved in advance.

3.4.6 Where the grain refining elements Niobium, Titanium and Vanadium are used either singly or in combination, the chemical composition is to be specifically approved for each Grade in combination with the rolling procedure to be used.

3.4.7 When any grade is supplied in an approved thermomechanically controlled processed condition, variations in the specified chemical composition may be considered, provided that these variations are documented and approved in advance.

3.4.8 For plate supplied from coil, the chemical analysis can be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

Table 3.3.2 Chemical composition

Grades	AH, DH, EH	FH
Carbon % max. Manganese % Silicon % max. Phosphorus % max. Sulphur % max.	0,18 0,9 – 1,60 (*see* Note 1) 0,50 0,035 0,035	0,16 0,9 – 1,60 0,50 0,025 0,025
Grain refining elements (*see* Note 2) Aluminium (acid soluble) % Niobium % Vanadium % Titanium % Total (Nb + V + Ti) % (*see* Note 5)	 0,015 min. (*see* Note 3) 0,02 – 0,05 0,05 – 0,10 0,02 max. 0,12 max.	
Residual elements Nickel % max. Copper % max. Chromium % max. Molybdenum % max. Nitrogen % max.	 0,40 0,35 0,20 0,08	 0,80 0,35 0,20 0,08 0,009 (0,012 max. if Al is present)

NOTES
1. For AH grade steels in all strength levels and thicknesses up to 12,5 mm, the specified minimum manganese content is 0,70%.
2. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.
3. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is to be not less than 0,020%.
4. Alloying elements other than those listed above are to be included in the approved manufacturing specification.
5. The grain refining elements are to be in accordance with the approved specification.

Table 3.3.3 Chemical composition for Grade AH 47, DH 47, EH 47 and FH 47

Chemical element	max. (%)
Carbon	0,20
Manganese	2,00
Silicon	0,55
Phosphorus	0,030
Sulphur	0,030
Nickel	2,00
Chromium	0,25
Molybdenum	0,080
Grain refining elements (*see* Note 1) Aluminium (acid soluble)	0,015 min (*see* Note 2)
Residual elements Copper 0,35	

NOTES
1. The grain refining elements niobium, vanadium and titanium are to be in accordance with the approved specification.
2. The total aluminium content may be determined instead of the acid soluble content. In these cases the total aluminium content is to be not less than 0,020%.

3.5 Condition of supply

3.5.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.3.5 or Table 3.3.6. Where alternative conditions are permitted, these are at the option of the steelmaker, unless otherwise expressly stated in the order for the material.

3.5.2 Where normalising rolling and thermomechanically controlled rolling (T.M.) processes are used, it is the manufacturer's responsibility to ensure that the programmed rolling schedules are adhered to. Where deviation from the programmed rolling schedule occurs, the manufacturer must ensure that each affected piece is tested and that the local Surveyor is informed.

3.5.3 The use of precipitation hardening steels is not acceptable, except where such hardening is incidental to the use of grain refining elements.

3.6 Mechanical tests

3.6.1 The results of all tensile tests and the average energy value from each set of three Charpy V-notch impact tests are to comply with the appropriate requirements given in Table 3.3.7 except where enhanced by the requirements of this Section.

3.6.2 For steels in the as-rolled, normalised, normalising rolled or T.M. conditions, one tensile test is to be made for each batch of 50 tonnes or fraction thereof. Additional tests are to be made for every variation of 10 mm in the thickness or diameter of products from the same cast.

3.6.3 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

3.6.4 For steels in the quenched and tempered condition a tensile test is to be made on each plate as heat treated. For continuously heat treated plates, one tensile test is to be made for each 50 tonnes or fraction thereof from a single cast. Additional tests are to be made for every variation of 10 mm in the thickness of the products from a single cast. The tensile test specimens are to be taken with their axes transverse to the main direction of rolling.

3.6.5 For products in the AH and DH grades, at least one set of three impact tests is to be made on the thickest piece in each batch of 50 tonnes when supplied in either the normalised or thermomechanically controlled condition. When the products are supplied in the as-rolled or normalising rolled conditions a set of impact test specimens is to be taken from a different piece from each 25 tonnes or fraction thereof. When supplied in the quenched and tempered condition, a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.6 For plates and wide flats in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on each piece. For plates supplied in the quenched and tempered condition a set of impact tests is to be made on each length as heat treated. Test specimens from the quenched and tempered plates are to have their axes transverse to the main rolling direction.

3.6.7 For plates and wide flats in H47 strength grade, one set of impact tests is to be made on each piece.

3.6.8 For sections and bars in the EH and FH grades supplied in the normalised or thermomechanically controlled conditions, one set of impact tests is to be made on the thickest piece in a batch not exceeding 25 tonnes. For sections supplied in the as-rolled or normalising rolled conditions the batch size is not to exceed 15 tonnes.

3.6.9 For batch tested plates in a condition other than furnace normalised, with a thickness equal to 12 mm or greater, and where the average value of one set of tests is less than 50 J, two further items from the same batch are to be selected and tested. If these fail to achieve an average of 50 J on either set, each individual piece of the heat is to be tested. The plates are acceptable provided they meet the requirements of Table 3.3.7. Additional testing is not required where the manufacturer can demonstrate to the satisfaction of the Surveyor that the plate was rolled outside the limits of the programmed rolling schedule. In this instance the plate should be rejected, *see also* 3.5.2.

3.6.10 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

Table 3.3.4 Carbon equivalent requirements for higher tensile strength steels up to 100 mm in thickness when supplied in the TM condition

Grade				Carbon Equivalent, max. (%)	
				$t \leq 50$	$50 < t \leq 100$
AH 27S	DH 27S	EH 27S	FH 27S	0,36	0,38
AH 32	DH 32	EH 32	FH 32	0,36	0,38
AH 36	DH 36	EH 36	FH 36	0,38	0,40
AH 40	DH 40	EH 40	FH 40	0,40	0,42
AH 47	DH 47	EH 47	FH 47	Not applicable (*see* Table 3.3.1)	0,49

NOTE
t = thickness, in mm.

Table 3.3.5 Conditions of supply for plates and wide flats

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)				
AH 27S AH 32 AH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 3)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	–	N	NR	TM	
AH 40	Any practice	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
AH 47 DH 47 EH 47 FH 47	Any practice	≤ 50	Not applicable				
		>50 ≤100	TM				
DH 27S DH 32 DH 36	Al or Al + Ti	≤ 20	AR	N	NR	TM	
		>20 ≤ 100	—	N	NR	TM	(*see* Note 4)
	Nb or V or Al + (Nb or V) or Al + (Ti) + (Nb or V)	≤ 12,5	AR	N	NR	TM	
		>12,5 ≤ 100	—	N	NR	TM	
DH 40	Any practice	≤ 50	—	N	NR	TM	
		>50 ≤ 100	—	N	—	TM	QT
EH 27S EH 32 EH 36	Any practice	≤ 100	—	N	—	TM	
EH 40	Any practice	≤ 100	—	N	—	TM	QT
FH 27S FH 32 FH 36 FH 40	Any practice	≤ 100	—	N	—	TM	QT

NOTES
1. Grain refining elements used singly or in any combination, require specific approval from Materials and NDE Department, London office.
2. AR = as-rolled N = furnace normalised NR = normalising rolled
   TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Material up to 35 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.
4. Material up to 25 mm thick may be supplied in the as-rolled condition provided that prior approval has been obtained from LR.

3.7 Identification of materials

3.7.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint. Where a number of light products are bundled, the bundle is to be identified in accordance with 1.10.2.

3.7.2 Steels which have been specially approved and which differ from the requirements of this Section are to have the letter 'S' after the agreed identification mark.

3.8 Certification of materials

3.8.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, the chemical composition is to include the contents of any grain refining elements used and of the residual elements.

3.8.2 For steels which have been specially approved, the agreed identification mark, the specified minimum yield stress and, if applicable, the contents of alloying elements are additionally to be stated on the test certificate or shipping statement.

Table 3.3.6 Conditions of supply for sections and bars

Grade	Grain refining practice (*see* Note 1)	Thickness range mm	Conditions of supply (*see* Note 2)			
AH 27S AH 32 AH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
AH 40	Any practice	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	
DH 27S DH 32 DH 36	Al or Al + Ti	≤20	Any			
		>20 ≤50	N	NR	TM	(*see* Note 3)
	Nb or V or Al + Nb or Al + V or Al + (Ti) + (Nb or V)	≤12,5	Any			
		>12,5 ≤50	N	NR	TM	(*see* Note 3)
DH 40	Any practice	≤50	N	NR	TM	
EH 27S EH 32 EH 36	Any practice	≤50	N	TM		(*see* Notes 3 and 4)
EH 40	Any practice	≤50	N	TM	QT	
FH 27S FH 32 FH 36 FH 40	Any practice	≤50	N	TM	QT	(*see* Note 4)

NOTES
1. Grain refining elements used singly or in any combination require specific approval from Materials and NDE Department, London Office.
2. N = furnace normalised NR = normalising rolled
   TM = thermomechanically controlled-rolled QT = quenched and tempered
3. Subject to the special approval of LR, sections may be supplied in the as-rolled condition provided satisfactory results are consistently obtained from Charpy V-notch impact tests.
4. Subject to the special approval of LR, sections may be supplied in the NR condition.

3.8.3 The steelmaker is to provide the Surveyor with a written declaration as detailed in 1.11.2.

Table 3.3.7 Mechanical properties for acceptance purposes (*see* Note 1)

Grades (*see* Note 3)	Yield Stress N/mm^2 min.	Tensile Strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min. (*see* Note 2)	Charpy V-notch impact tests (*see* Notes 3, 4 and 5) Average energy J minimum					
				$t \le 50$ mm		$50 < t \le 70$ mm		$70 < t \le 100$ mm	
				Longitudinal	Transverse	Longitudinal	Transverse	Longitudinal	Transverse
AH 27S DH 27S EH 27S FH 27S	265	400 – 530	22	27	20	34	24	41	27
AH 32 DH 32 EH 32 FH 32	315	440 – 570	22	31	22	38	26	46	31
AH 36 DH 36 EH 36 FH 36	355	490 – 630	21	34	24	41	27	50	34
AH 40 DH 40 EH 40 FH 40	390	510 – 650	20	39	26	46	31	55	37
AH 47 DH 47 EH 47 FH 47	460	570 – 720	17	—	—	53	35	64	42

Impact tests are to be made on the various grades at the following temperatures:

AH grades 0°C
DH grades –20°C
EH grades –40°C
FH grades –60°C

NOTES
1. The requirements for products thicker than those detailed in the table are subject to agreement, *see* 3.1.4.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm, *see* Fig. 2.2.4 in Chapter 2, the minimum elongation is to be:

Thickness mm		≤5	>5 ≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤30	>30 ≤40	>40 ≤50	>50
Elongation %	Strength levels 27S, 32	14	16	17	18	19	20	21	22	To be specially agreed
	Strength level 36	13	15	16	17	18	19	20	21	
	Strength level 40	12	14	15	16	17	18	19	20	

3. Subject to special approval by LR, the minimum tensile strength may be reduced to 470 N/mm^2, for grades AH36, DH36, EH36 and FH36, in the TM condition when micro-alloying elements Nb, Ti or V are used singly and not in combination and provided the yield to tensile strength ratio does not exceed 0,89. For plates with a thickness ≤12 mm, the yield to tensile strength ratio is to be specially considered.
4. Tests are to be taken in the longitudinal direction. Normally, transverse test specimens are not required. Transverse test results for plates and wide flats are to be guaranteed by the supplier.
5. *See* 1.7.11
6. *See* 3.6.9.
7. For steel of H47 strength grade, the yield to tensile strength ratio is not to exceed 0,94.

Section 4
Steels for boilers and pressure vessels

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and alloy steels intended for use in the construction of boilers and pressure vessels. In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements also give details of appropriate mechanical properties at elevated temperatures which may be used for design purposes.

4.1.2 Where it is proposed to use a carbon or carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and mechanical properties at elevated temperatures may be obtained by interpolation.

4.1.3 Carbon and carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2 but not exceeding 520 N/mm^2 may be accepted, provided that details of the proposed specification are submitted for approval.

4.1.4 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases the specified minimum tensile strength is not to exceed 600 N/mm^2.

4.1.5 Materials intended for use in the construction of the cargo tanks and process pressure vessels storage tanks for liquefied gases and for other low temperature applications are to comply with the requirements of Section 6 or 7, as appropriate.

4.2 Manufacture and chemical composition

4.2.1 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements of Table 3.4.1.

4.2.2 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

4.3 Heat treatment

4.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.4.2 except that, when agreed, material intended for hot forming may be supplied in the as-rolled condition.

4.4 Mechanical tests

4.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

4.4.2 For strip, tensile test specimens are to be taken from both ends of each coil.

4.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

4.4.4 Where plates are required for hot forming and it has been agreed that the heat treatment will be carried out by the fabricator, the tests at the steelworks are to be made on material which has been cut from the plates and given a normalising and tempering heat treatment in a manner simulating the treatment which will be applied to the plates.

4.4.5 If required by the Surveyors or by the fabricator, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order together with agreed details of the simulated heat treatment and the mechanical properties which can be accepted.

4.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Tables 3.4.3 to 3.4.5.

4.4.7 Where plate is supplied from coil, the tensile tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

4.4.8 All test specimens are to be taken in the transverse direction unless otherwise agreed.

4.4.9 When material will be subject to strains in a through thickness direction, it is recommended that it should have specified through thickness properties in accordance with the requirements of Section 8.

4.5 Identification of materials

4.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

Table 3.4.1 Chemical composition and deoxidation practice

Grade of steel	Deoxidation	Chemical composition %						
Carbon and carbon-manganese steels		C max.	Si	Mn	P	S	Al	Residual elements
360 AR	Any method except rimmed steel	0,18	0,50 max.	0,40 – 1,20	0,040 max.		–	Cr 0,25 max. Cu 0,30 max. Mo 0,10 max. Ni 0,30 max. Total 0,70 max.
410 AR		0,21		0,40 – 1,30			–	
460 AR		0,23		0,80 – 1,50			–	
360	Any method except rimmed steel	0,17	0,35 max.	0,40 – 1,20	0,035 max.		–	
410		0,20		0,50 – 1,30			–	
460		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,40			–	
490	Killed		0,10 – 0,50	0,90 – 1,60			–	
360 FG	Killed fine grained	0,17	0,35 max.	0,40 – 1,20	0,035 max.		(*see* Note 2)	
410 FG		0,20		0,50 – 1,30				
460 FG		0,20 (*see* Note 1)	0,40 max.	0,80 – 1,50				
490 FG			0,10 – 0,50	0,90 – 1,60				
510 FG		0,22						

Alloy steel		C	Si	Mn	P S	Al	Cr	Mo	Residual elements
13Cr Mo 45	Killed	0,10–0,18	0,15–0,35	0,4–0,8	0,035 max.	(*see* Note 3)	0,70–1,30	0,40–0,60	Cu 0,30 max.
11Cr Mo 910		0,08–0,18	0,15–0,50				2,00–2,50	0,90–1,10	Ni 0,30 max.

NOTES
1. For thicknesses greater than 30 mm, carbon 0,22% max.
2. Aluminium (acid soluble) 0,015% min. or
   Aluminium (total) 0,018% min.
   Niobium, vanadium or other suitable grain refining elements may be used either in place of or in addition to aluminium.
3. Aluminium (acid soluble or total) 0,020% max.

Table 3.4.2 Condition of supply

Grade of steel	Condition of supply
Carbon and carbon-manganese 360 AR to 460 AR	As-rolled Maximum thickness or diameter is 40 mm
Carbon and carbon-manganese 360 to 490	Normalised or normalised rolled
Carbon and carbon-manganese 360 FG to 510 FG	Normalised or normalised rolled
13Cr Mo 45	Normalised and tempered
11Cr Mo 910	Normalised and tempered

Table 3.4.3 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – As-rolled

Grade of steel	Thickness mm	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360 AR	≤ 40	190	360–480	24
410 AR		215	410–530	22
460 AR		240	460–580	21

Table 3.4.4 Mechanical properties for acceptance purposes: carbon and carbon-manganese steels – Normalised or normalised rolled

Grade of steel	Thickness mm (*see* Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
360	>3 ≤16 >16 ≤40 >40 ≤63	205 195 185	360 – 480	26 26 25
410	>3 ≤16 >16 ≤40 >40 ≤63	235 225 215	410 – 530	24 24 23
460	>3 ≤16 >16 ≤40 >40 ≤63	285 255 245	460 – 580	22 22 21
490	>3 ≤16 >16 ≤40 >40 ≤63	305 275 265	490 – 610	21 21 20
360 FG	>3 ≤16 >16 ≤40 >40 ≤63	235 215 195	360 – 480	26 26 25
410 FG	>3 ≤16 >16 ≤40 >40 ≤63	265 245 235	410 – 530	24 24 23
460 FG	>3 ≤16 >16 ≤40 >40 ≤63	295 285 275	460 – 580	22 22 21
490 FG	>3 ≤16 >16 ≤40 >40 ≤63	315 315 305	490 – 610	21 21 21
510 FG	>3 ≤16 >16 ≤40 >40 ≤63	355 345 335	510 – 650	21

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

Table 3.4.5 Mechanical properties for acceptance purposes: alloy steels – Normalised and tempered

Grade of steel	Thickness mm (see Note)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum
13Cr Mo45	≤63	305	470–620	20
11Cr Mo910	≤16 >16 ≤63	275 265	480–630	18

NOTE
For thicknesses greater than 63 mm, the minimum values for yield stress may be reduced by 1% for each 5 mm increment in thickness over 63 mm. The minimum elongation values may also be reduced one unit, e.g. for all thicknesses over 63 mm. For thicknesses over 100 mm, the above values are to be agreed.

4.6 Certification of materials

4.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and to give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the content of any grain refining elements used and of the residual elements, as detailed in Table 3.4.1.

4.7 Mechanical properties for design purposes

4.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Tables 3.4.6 to 3.4.8.

4.7.2 These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than given in Tables 3.4.6 to 3.4.8.

Table 3.4.6 Mechanical properties for design purposes (*see* 4.7.1) **: carbon and carbon-manganese steels – As-rolled**

Grade of steel	Thickness mm	Design temperature °C (*see* Note)						
		50	100	150	200	250	300	350
		Nominal minimum lower yield or 0,2% proof stress N/mm^2						
360 AR	≤ 40	154	153	152	145	128	108	102
410 AR	≤ 40	186	183	181	174	155	134	127
460 AR	≤ 40	218	213	210	203	182	161	153

NOTE
Maximum permissible design temperature is 350°C.

4.7.3 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on material from each cast. Where materials of more than one thickness are supplied from one cast, the thickest material is to be tested. The test specimens are to be prepared from material adjacent to that used for tests at ambient temperature. The axis of the test specimens, is to be between mid and quarter thickness of the material and the test specimens are to be machined to dimensions in accordance with the requirements of Chapter 2. The test procedure is also to be as detailed in Chapter 2, and the results are to comply with the requirements of the National or proprietary specifications.

4.7.4 As an alternative to 4.7.3, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes but, at the discretion of the Surveyors, occasional check tests of this type may be requested.

Table 3.4.7 Mechanical properties for design purposes (*see* 4.7.1)**: carbon and carbon-manganese steels – Normalised or controlled-rolled**

Grade of steel	Thickness mm (*see* Note)	Design temperature °C								
		50	100	150	200	250	300	350	400	450
		Nominal minimum lower yield or 0,2% proof stress N/mm^2								
360	>3 ≤16	183	175	172	168	150	124	117	115	113
	>16 ≤40	173	171	169	162	144	124	117	115	113
	>40 ≤63	166	162	158	152	141	124	117	115	113
410	>3 ≤16	220	211	208	201	180	150	142	138	136
	>16 ≤40	204	201	198	191	171	150	142	138	136
	>40 ≤63	196	192	188	181	168	150	142	138	136
460	>3 ≤16	260	248	243	235	210	176	168	162	158
	>16 ≤40	235	230	227	220	198	176	168	162	158
	>40 ≤63	227	222	218	210	194	176	168	162	158
490	>3 ≤16	280	270	264	255	228	192	183	177	172
	>16 ≤40	255	248	245	237	214	192	183	177	172
	>40 ≤63	245	240	236	227	210	192	183	177	172
360 FG	>3 ≤16	214	204	185	165	145	127	116	110	106
	>16 ≤40	200	196	183	164	145	127	116	110	106
	>40 ≤63	183	179	172	159	145	127	116	110	106
410 FG	>3 ≤16	248	235	216	194	171	152	141	134	130
	>16 ≤40	235	228	213	192	171	152	141	134	130
	>40 ≤63	222	215	204	188	171	152	141	134	130
460 FG	>3 ≤16	276	262	247	223	198	177	167	158	153
	>16 ≤40	271	260	242	220	198	177	167	158	153
	>40 ≤63	262	251	235	217	198	177	167	158	153
490 FG	>3 ≤16	297	284	265	240	213	192	182	173	168
	>16 ≤40	293	279	260	237	213	192	182	173	168
	>40 ≤63	286	272	256	234	213	192	182	173	168
510 FG	>3 ≤63	313	290	270	255	235	215	200	180	—

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

Table 3.4.8 Mechanical properties for design purposes (*see* 4.7.1)**: alloy steels – Normalised and tempered**

Grade of steel	Thickness mm (see Note)	Design temperature °C									
		50	100	200	300	350	400	450	500	550	600
		Nominal minimum lower yield or 0,2% proof stress N/mm^2									
13CrMo 45	>3 ≤63	284	270	248	216	203	199	194	188	181	174
11CrMo 910	>3 ≤63	255	249	233	219	212	207	194	180	160	137

NOTE
For thicknesses greater than 63 mm, the values for lower yield or 0,2% proof stress are to be reduced by 1% for each 5 mm increment in thickness up to 100 mm. For thicknesses over 100 mm, the values are to be agreed and verified by test.

4.7.5 Values for the estimated average stress to rupture in 100 000 hours are given in Table 3.4.9 and may be used for design purposes.

Table 3.4.9 Mechanical properties for design purposes (*see* 4.7.5)**: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)**

Temperature °C	Grades of steel				
	Carbon and carbon-manganese			Low alloy	
	360FG 410FG 460FG	360 410 460	490 490FG 510FG	13CrMo 45	11CrMo 910
380	171	219	227	—	—
390	155	196	203	—	—
400	141	173	179	—	—
410	127	151	157	—	—
420	114	129	136	—	—
430	102	109	117	—	—
440	90	92	100	—	—
450	78	78	85	290	—
460	67	67	73	262	—
470	57	57	63	235	210
480	47	48	55	208	186
490	36	—	47	181	165
500	—	—	—	155	145
510	—	—	—	129	128
520	—	—	—	103	112
530	—	—	—	80	98
540	—	—	—	62	84
550	—	—	—	49	72
560	—	—	—	42	61
570	—	—	—	36	51
580	—	—	—	—	44

■ *Section 5*
Steels for machinery fabrications

5.1 General

5.1.1 Steel plates, sections or bars intended for use in the construction of major components of welded machinery structures, such as bedplates, crankcases, frames and entablatures, are to comply with one of the following alternatives:

(a) Any grade of normal strength structural steel as detailed in Section 2.
(b) Any grade of higher tensile structural steel as detailed in Section 3.
(c) Any grade of carbon-manganese boiler or pressure vessel steel as detailed in Section 4, except that for this application batch testing is acceptable. The size of a batch and the number of tensile tests are to be as detailed in Section 2.

5.1.2 The minus tolerances for products for machinery structures are to be in accordance with Table 3.5.1.

Table 3.5.1 Under thickness tolerances

Nominal thickness, *t* (mm)	Minus tolerance (mm)
5 ≤ *t* < 8	–0,4
8 ≤ *t* < 15	–0,5
15 ≤ *t* <25	–0,6
25 ≤ *t* < 40	–0,8
t ≥ 40	–1,0

5.2 Certification of materials

5.2.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements.

■ *Section 6* Ferritic steels for low temperature service

6.1 Scope

6.1.1 This Section gives specific requirements for carbon-manganese and nickel alloy steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases.

6.1.2 The requirements of this Section are also applicable for other types of pressure vessels where the use of steels with guaranteed impact properties at low temperatures is required.

6.1.3 Provision is made for plates and sections up to 40 mm thick.

6.1.4 Steels with alternative chemical compositions or mechanical properties or in a different supply condition may be given special consideration.

6.2 Manufacture and chemical composition

6.2.1 All steels are to be in the killed and fine grain treated condition.

6.2.2 The chemical compositions of carbon-manganese steels are to comply with the appropriate requirements for Grades AH, DH, EH and FH strength levels 27S, 32, 36 and 40, *see* Table 3.3.2. For the uses defined in 6.1.1 and 6.1.2, however, these grades are to be designated LT–AH, LT–DH, LT–EH and LT–FH respectively.

6.2.3 The chemical compositions of nickel alloy steels are to comply with the appropriate requirements of Table 3.6.1.

6.2.4 For plate supplied from coil, the chemical analysis may be transposed from the certificate of the coil manufacture onto the re-processor's certificate.

6.3 Heat treatment

6.3.1 All materials are to be supplied in a condition complying with the requirements given in Table 3.6.2.

Table 3.6.2 Supply conditions

Grade	Plates	Sections and bars
LT – AH	N TM	Any
LT – DH		
LT – EH	Normalised (*see* Note) T.M.C.P. Quenched and tempered	
LT – FH		N TM
1 1/2 Ni 3 1/2 Ni 5Ni	Normalised (*see* Note) Normalised and tempered Quenched and tempered	
9Ni	Double normalised and tempered Quenched and tempered	
NOTE Where the term 'Normalised' is used it does not include normalising rolling.		

6.4 Mechanical tests

6.4.1 For plates, a tensile test specimen is to be taken from one end of each piece when the mass does not exceed 5 tonnes and the length does not exceed 15 m. When either of these limits is exceeded, tensile test specimens are to be taken from both ends of each piece. A piece is to be regarded as the rolled product from a single slab or from a single ingot if this is rolled directly into plates.

6.4.2 For strips, tensile test specimens are to be taken from both ends of each coil.

Table 3.6.1 Chemical compositions of nickel alloy steels

Grade of steel	C	Si	Mn	Ni	P	S	Residual elements	Aluminium
1 1/2 Ni	0,18 max.	0,10 – 0,35	0,30 – 1,50	1,30 – 1,70	0,025 max.	0,020 max.	Cr 0,25 max. Cu 0,35 max. Mo 0,08 max. Total 0,60 max.	Total 0,020% min. Acid soluble 0,015% min.
3 1/2 Ni	0,15 max.		0,30 – 0,90	3,20 – 3,80				
5Ni	0,12 max.			4,70 – 5,30				
9Ni	0,10 max.			8,50 – 10,0				

6.4.3 Sections and bars are to be presented for acceptance test in batches containing not more than 50 lengths, as supplied. The material in each batch is to be of the same section size, from the same cast and in the same condition of supply. One tensile test specimen is to be taken from material representative of each batch, except that additional tests are to be taken when the mass of a batch exceeds 10 tonnes.

6.4.4 One set of three Charpy V-notch impact test specimens is to be taken for each tensile test specimen required.

6.4.5 For plates, these impact test specimens are to be cut with the principal axis perpendicular to the final direction of rolling. For sections, the impact test specimens are to be taken longitudinally.

6.4.6 The results of all tensile tests are to comply with the appropriate requirements given in Table 3.6.3. The ratio between the yield stress and the tensile strength is not to exceed 0,9 for normalised and TM steels and 0,94 for QT steels.

6.4.7 The average value for the three impact tests is to comply with the appropriate requirements given in Table 3.6.3. One individual value may be less than the required value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

6.4.8 Where standard subsidiary impact specimens are necessary, *see* Ch 2,3.2.4.

6.4.9 Where plate is supplied from coil, both the tensile tests and the Charpy V-notch tests are to be taken from the de-coiled plate in accordance with the frequency specified for the Grade as required by this Section.

6.5 Identification of materials

6.5.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

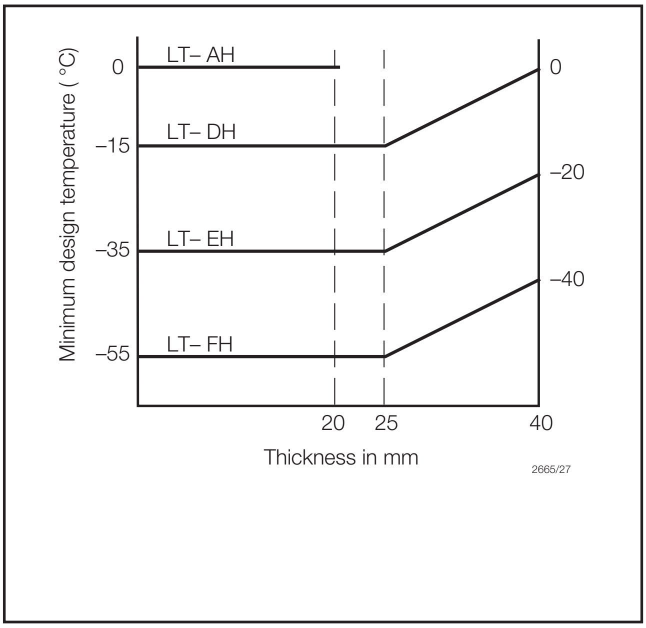
Table 3.6.3 Mechanical properties for acceptance purposes (*see* Note 1)

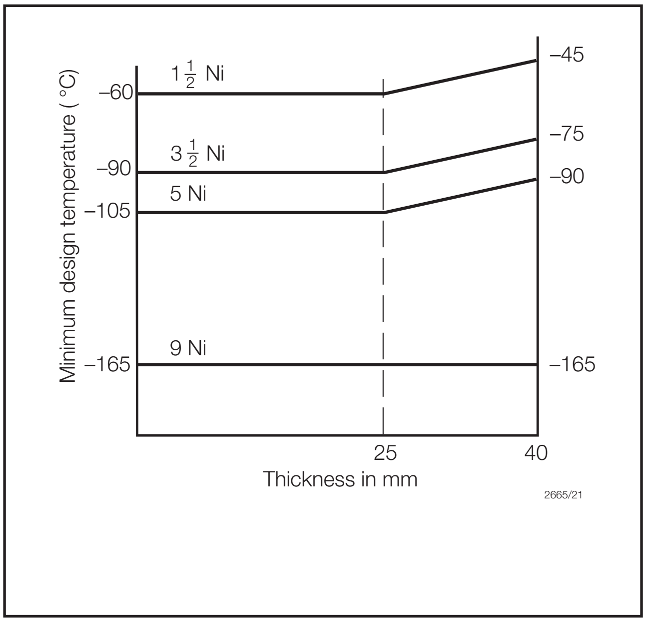
Grade of steel	Yield stress N/mm^2 min.	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % min.	Charpy V-notch impact tests (*see* Note 3)	
				Test temp. °C	Impact energy
LT – AH 27S	265	400 – 530	22	0	Plates – transverse tests Average energy 27 J min Sections and bars – longitudinal tests Average energy 41 J min
LT – AH 32	315	440 – 590	22		
LT – AH 36	355	490 – 620	21		
LT – AH 40	390	510 – 650	20		
LT – DH 27S	265	400 – 530	22	–20	
LT – DH 32	315	440 – 590	22		
LT – DH 36	355	490 – 620	21		
LT – DH 40	390	510 – 650	20		
LT – EH 27S	265	400 – 530	22	–40	
LT – EH 32	315	440 – 590	22		
LT – EH 36	355	490 – 620	21		
LT – EH 40	390	510 – 650	20		
LT – FH 27S	265	400 – 530	22	–60	
LT – FH 32	315	440 – 590	22		
LT – FH 36	355	490 – 620	21		
LT – FH 40	390	510 – 650	20		
$1^1/_2$ Ni	275	490 – 640	22	–65	
$3^1/_2$ Ni	285	450 – 610	21	–95	
5Ni	390	540 – 740	21	–110	
9Ni	490	640 – 790	18	–196	

NOTES
1. These requirements are applicable to products not exceeding 40 mm in thickness. The requirements for thicker products are subject to agreement.
2. The minimum design temperatures at which plates of different thicknesses in the above grades may be used are given in Fig. 3.6.1 and Fig. 3.6.2. Consideration will be given to the use of thicknesses greater than those in the Tables or to the use of design temperatures below –165°C.
3. Impact tests are not required on thicknesses less than 6 mm.

6.6 Certification of materials

6.6.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 together with general details of the heat treatment. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Tables 3.3.2 or 3.6.1.





Section 7
Austenitic and duplex stainless steels

7.1 Scope

7.1.1 Provision is made in this Section for rolled products in austenitic and duplex (austenite plus ferrite) stainless steels intended for use in the construction of cargo tanks, storage tanks and process pressure vessels for chemicals and liquefied gases.

7.1.2 Austenitic stainless steels are suitable for applications where the lowest design temperature is not lower than –165°C.

7.1.3 Austenitic stainless steels are also suitable for service at elevated temperatures, and for such applications the proposed specification should contain, in addition to the requirements of 7.1.6, minimum values for 0,2 and 1,0 per cent proof stresses at the design temperature.

7.1.4 Duplex stainless steels are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels below 0°C will be subject to special consideration.

7.1.5 Duplex stainless steels are also suitable for service at temperatures up to 300°C, and for such applications the proposed specification should include, in addition to the requirements of 7.1.6, a minimum value for 0,2 per cent proof stress at the design temperature.

7.1.6 A specification giving details of the chemical composition, heat treatment and mechanical properties, including, for the austenitic grades, both the 0,2 and 1,0 per cent proof stresses, is to be submitted for consideration and approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 3.7.1.

7.2.2 Consideration will be given to the use of steels whose compositions are outside the scope of Table 3.7.1.

7.3 Heat treatment

7.3.1 All materials are to be supplied in the solution treated condition.

7.4 Mechanical tests

7.4.1 Tensile test specimens are to be taken in accordance with the appropriate requirements of 4.4 and 6.4.1.

Table 3.7.1 Chemical composition

Type and grade of steel	Chemical composition % (*see* Note)									
	C	Si	Mn	P	S	Cr	Ni	Mo	N	Other
Austenitic										
304 L						17,0—20,0	8,0—13,0	—	0,10	—
304 LN						17,0—20,0	8,0—12,0	—	0,10—0,22	—
316 L	0,03					16,0—18,5	10,0—15,0	2,0—3,0	0,10	—
316 LN		1,0	2,0	0,045	0,03	16,0—18,5	10,0—14,5	2,0—3,0	0,10—0,22	—
317 L						18,0—20,0	11,0—15,0	3,0—4,0	0,10	—
317 LN						18,0—20,0	12,5—15,0	3,0—4,0	0,10—0,22	—
321	0,08					17,0—19,0	9,0—12,0	—	0,10	5 x C ≤ Ti ≤ 0,7
347	0,08					17,0—19,0	9,0—13,0	—	0,10	10 x C ≤ Nb ≤ 1,0
Duplex										
UNS S 31803	0,03	1,0	2,0	0,03	0,02	21,0—23,0	4,5—6,5	2,5—3,5	0,08—0,20	—
UNS S 32750	0,03	0,80	1,2	0,035	0,02	24,0—26,0	6,0—8,0	3,0—5,0	0,24—0,32	Cu 0,50 max.

NOTE
All figures are a maximum value except where a range is shown.

Table 3.7.2 Mechanical properties for acceptance purposes

Type and grade of steel	0,2% Proof stress (N/mm^2) minimum	1% Proof stress (N/mm^2) minimum	Tensile strength (N/mm^2) minimum	Elongation on $5,65\sqrt{S_o}$ % minimum
Austenitic				
304L	170	210	485	40
304LN	205	245	515	40
316L	170	210	485	40
316LN	205	245	515	40
317L	205	245	515	40
317LN	240	280	550	40
321	205	245	515	40
347	205	245	515	40
Duplex				
UNS S 31803	450	—	620	25
UNS S 32750	550	—	795	15

7.4.2 For the duplex grades, one set of three Charpy V-notch impact test specimens machined from the longitudinal direction for each tensile test is to be tested at –20°C. The average energy value of the three specimens is to be not less than 41 Joules.

7.4.3 Unless otherwise agreed, impact tests are not required from the austenitic grades of steel given in this Section.

7.4.4 Where standard subsidiary Charpy V-notch test specimens are necessary, *see* Ch 2,3.2.4.

7.4.5 The results of all tensile tests are to comply with the requirements of Table 3.7.2 or the approved specification.

7.5 Through thickness tests

7.5.1 Where material will be strained in a through thickness direction during welding or in service, through thickness tests are required on plates over 10 mm thick in all the grades of steels listed in Table 3.7.1, apart from Grades 304L, 304 LN, 321 and 347.

7.5.2 Testing is to conform with the requirements of Section 8, with the exception given in 7.5.3.

7.5.3 When the reduction in area is less than 35 per cent, metallographic or other evidence is required to show that no significant amount of any detrimental phase, such as sigma, is present.

7.6 Intergranular corrosion tests

7.6.1 For certain specific applications such as storage tanks for chemicals, it may be necessary to demonstrate that the material used is not susceptible to intergranular corrosion resulting from grain boundary precipitation of chromium-rich carbides.

7.6.2 When required, one test of this type is to be carried out for each tensile test. The material for the test is to be taken adjacent to that for the tensile test.

7.6.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be as given in 7.6.4, *see* Ch 2,8.

7.6.4 Wherever practical, exposed cut edges should be avoided. However, where any such edges are to remain after fabrication is completed, it is to be shown by an appropriate test, that the corrosion resistance is adequate for the cargoes expected to be encountered.

7.7 Clad plates

7.7.1 Carbon or carbon-manganese steel plates, clad on one or both surfaces with a suitable grade of austenitic or duplex stainless steel, may be used for the construction of cargo or storage tanks for chemicals.

7.7.2 The carbon or carbon-manganese steel base plates are to comply with the requirements of Section 4, and the austenitic cladding material generally with the requirements of this Section.

7.7.3 The process of manufacture is to be specially approved and may be either by roll cladding, or by explosive bonding.

7.7.4 Where the use of clad materials is proposed, the material specification is to be submitted for consideration, together with details of the extent, and the acceptance standards for non-destructive examination.

7.8 Identification of materials

7.8.1 The particulars detailed in 1.10 are to be marked on all materials which have been accepted.

7.9 Certification of materials

7.9.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, where applicable, the results obtained from intercrystalline corrosion tests, and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements, as detailed in Table 3.7.1.

Section 8
Plates with specified through thickness properties

8.1 Scope

8.1.1 Provision is made in this Section for 'Z' grade plate and wide flat material with improved ductility in the through thickness or 'Z' direction, *see* Fig. 3.8.1. The use of this material is recommended for certain types of welded structures (*see* 1.2) in order to minimise the possibility of lamellar tearing either during fabrication or erection.

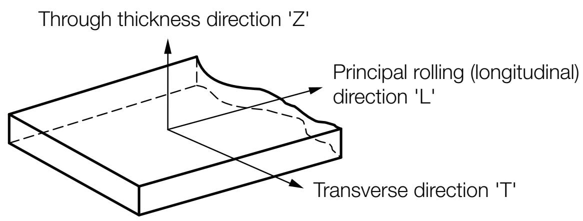


Fig. 3.8.1 Schematic of testing directions

8.1.2 Through thickness properties are characterised by specified values for reduction of area in a through thickness tensile test.

8.1.3 Provision is made for two grades Z25 and Z35. For normal ship applications the Z25 grade is applicable, whilst the Z35 grade is for more severe applications.

8.1.4 This 'Z' grade material is to comply with the requirements of Sections 2, 3, 4, 5 and 6 as appropriate, and the additional requirements of this Section.

8.1.5 The test procedure detailed in this Section may also be used to demonstrate that no unacceptable amount of banding of any detrimental phase, such as sigma is present, *see* 7.5.

8.2 Manufacture

8.2.1 All plates and wide flats are to be manufactured at works, which have been approved by LR for this quality of material.

8.2.2 It is recommended that the steel should be efficiently vacuum de-gassed. The sulphur content is not to exceed 0,008 per cent.

8.2.3 Consideration will be given to proposals for alternative methods of improving through thickness properties.

8.3 Test material

8.3.1 Unless otherwise agreed, through thickness tensile tests are only required for plate materials where the thickness exceeds 15 mm for carbon and alloy steels, or 10 mm in the case of austenitic and duplex stainless steels.

8.3.2 For plates and wide flats, one test sample is to be taken close to the longitudinal centreline from one end of each rolled piece representing the batch, *see* Table 3.8.1 and Fig. 3.8.2. The test sample must be large enough to accommodate the preparation of 6 specimens. 3 test specimens are to be prepared while the rest of the sample remains for possible retest.

8.3.3 The dimensions of the test specimens are to be in accordance with Ch 2,2.1.12.

Table 3.8.1 Batch size dependent on product and sulphur content

Product	S > 0,005%	$S \leq$ 0,005%
Plates	Each piece (parent plate)	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness ≤ 25 mm	Maximum 10 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment
Wide flats of nominal thickness > 25 mm	Maximum 20 *t* of products of the same cast, thickness and heat treatment	Maximum 50 *t* of products of the same cast, thickness and heat treatment

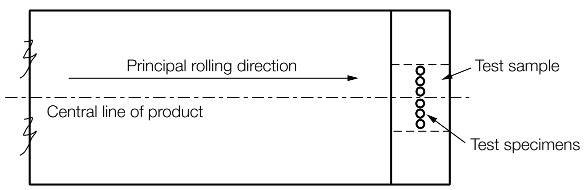


Fig. 3.8.2
Plate and wide flat sampling position

8.3.4 Alternatively, test sampling may be carried out in accordance with an accepted National or International Standard.

8.4 Mechanical tests

8.4.1 The three through thickness tensile test specimens are to be tested at ambient temperature, and for acceptance are to give a minimum average reduction of area value of not less than that shown in Table 3.8.2. Only one individual value may be below the minimum average, but should not be less than the minimum individual value shown for the appropriate grade.

Table 3.8.2 Reduction of area acceptance values

Grade	Z25	Z35
Minimum average	25%	35%
Minimum individual	15%	25%

8.4.2 If the average value fails to comply with 8.4.1, three additional tests may be made on specimens from the same test sample. The results of these tests are to be added to those previously obtained to form a new average, which for acceptance is to be not less than 25 per cent for grade Z25 or 35 per cent for grade Z35. No individual results in the re-test shall be below 25 per cent for grade Z25 or 35 per cent for grade Z35, *see* Fig. 3.8.3.

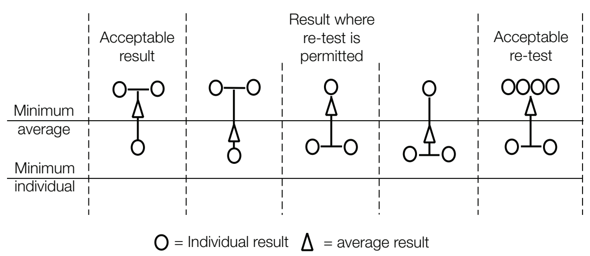


Fig. 3.8.3
Diagram showing acceptance/rejection and re-test criteria

8.4.3 Where batch testing is permitted, and failure after re-test occurs, the tested piece is to be rejected. Each remaining piece in the batch may be individually tested and accepted, based on satisfactory results.

8.4.4 If the fracture of a test specimen occurs in the weld or in the heat affected zone the test is to be regarded as invalid and is to be repeated on a new test specimen.

8.5 Non-destructive examination

8.5.1 All 'Z' grade plates are to be ultrasonically tested in the final supply condition with a probe frequency of 3-5 MHz. The testing is to be performed in accordance with and in compliance with either EN 10160 Level S1/E1 or ASTM A 578 Level C.

8.6 Identification of materials

8.6.1 Products which comply with the requirements of this Section are to have the notation Z25 or Z35 added to the steel grade designation.

8.7 Certification of materials

8.7.1 The following information is required to be included on the certificate in addition to the appropriate steel grade requirements:

(a) Through thickness reduction in area (%), individual results and average.

(b) Steel grade with Z25 or Z35 notation.

8.7.2 Steel grade requirements are to comply with Sections 1 to 7.

■ *Section 9*
Bars for welded chain cables

9.1 Scope

9.1.1 Provision is made in this Section for rolled steel bars intended for the manufacture of three Grades (U1, U2 and U3) of stud link chain cable for the anchoring and mooring of ships and five Grades (R3, R3S, R4, R4S and R5) of offshore mooring cable.

9.1.2 For the ship grades, U1, U2 and U3, approval will permit the supply of bars of the appropriate grades and size to any chain cable manufacturer.

9.1.3 For the offshore grades, R3, R3S, R4, R4S and R5, approval is confined to bar to be supplied to a nominated chain manufacturer and will be given only after successful testing of a completed chain. Separate approvals are required if bar is to be supplied to more than one cable manufacturer. Approval of a higher grade does not cover approval of a lower grade, as all grades must be individually approved.

9.1.4 For all grades, approval is normally given for diameters of bars no greater than those of the bars used in procedure tests.

9.2 Manufacture

9.2.1 All grades of bar material are to be made from killed steel, and all grades of bar material except for Grade U1 chain cables are to be fine grained. For Grades R4S and R5 the austenite grain size is to be 6 or finer, in accordance with ASTM E112.

9.2.2 The bars are to be made to a specification approved by LR which should include the manufacturing procedure, deoxidation practice, heat treatment and mechanical properties.

9.2.3 The rolling reduction ratio of bars for Grades R3, R3S, R4, R4S and R5 must be at least 5:1.

9.3 Chemical composition

9.3.1 For Grades U1, U2 and U3 the chemical composition should be generally within the limits given in Table 3.9.1.

9.3.2 For Grades R3, R3S, R4, R4S and R5 the chemical composition is to comply with an approved specification, *see* 9.2.2.

9.3.3 For Grades R4, R4S and R5 chain cable the steel should contain a minimum of 0,2 per cent molybdenum. The reported composition is to include the contents of antimony, arsenic, tin, copper, nitrogen, aluminium and titanium.

Table 3.9.1 Chemical composition of killed steel bars

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	Nb max.	V max.	N max.	Cr max.	Cu max.	Ni max.	Mo max.
U1	0,20	0,15–0,35	0,40 min.	0,04	0,04	–	–	–	–	–	–	–	–
U2	0,24	0,15–0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	–	–	–	–	–	–	–
U3	0,33	0,15–0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,05 *see* Note 2	0,10 *see* Note 2	0,015	0,25	0,35	0,40	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

9.3.4 For Grades R4S and R5 the steel used must be vacuum degassed.

9.4 Heat treatment

9.4.1 Unless stipulated otherwise, the bars are to be supplied in the as-rolled condition, but the supplier is to be advised by the chain manufacturer of the heat treatment to be used for the completed chain in order that the mechanical test specimens may be tested in the condition of heat treatment used for the chain.

9.4.2 For Grades U1 and U2, the samples selected from each batch may be tested either in the as-rolled condition, or after heat treatment where the chain is to be used in the heat treated condition, in full cross-section and in a manner simulating the heat treatment applied to the finished cable.

9.4.3 For Grades U3, R3, R3S, R4, R4S and R5 the sample is to be tested after heat treatment as detailed in 9.4.2.

9.5 Embrittlement tests

9.5.1 For Grades R3, R3S, R4, R4S and R5 the bar manufacturer is to provide evidence that the material is not susceptible to strain ageing, or to temper brittleness under the conditions of manufacture of the chain. The results of the relevant tests are to be reported to LR at the approval stage. Approval will be restricted to the specified steel composition and if later this is altered then re-approval will be required. Temper brittleness testing may be waived, if the chain is to be quenched after tempering.

9.5.2 Each heat of steel bars of grades R3S, R4, R4S and R5 is to be tested for hydrogen embrittlement (*see* Ch 2,5.3). In the case of continuous casting, test samples representing both the beginning and the end of the charge are to be taken. In the case of ingot casting, test samples representing two different ingots are to be taken.

9.5.3 Each sample is to be heat treated in a manner simulating the heat treatment of the finished chain. From each sample, two specimens are to be prepared from the mid-diameter of the bar and tested in accordance with Ch 2,5.3.

9.5.4 The ratio Z_1/Z_2 is to be greater than or equal to 0,85, where Z_1 is the reduction in area without baking and Z_2 the reduction in area after baking.

9.5.5 If the requirement is not met, the material is to be subjected to a hydrogen degassing treatment which is subject to approval by LR. Further tests are to be performed after degassing.

9.6 Mechanical tests

9.6.1 Bars of the same nominal diameter are to be presented for test in batches of 50 tonnes or fraction thereof from the same cast. A suitable length from one bar in each batch is to be selected for test purposes. Test pieces are to be taken from the positions as shown in Fig. 3.9.1.

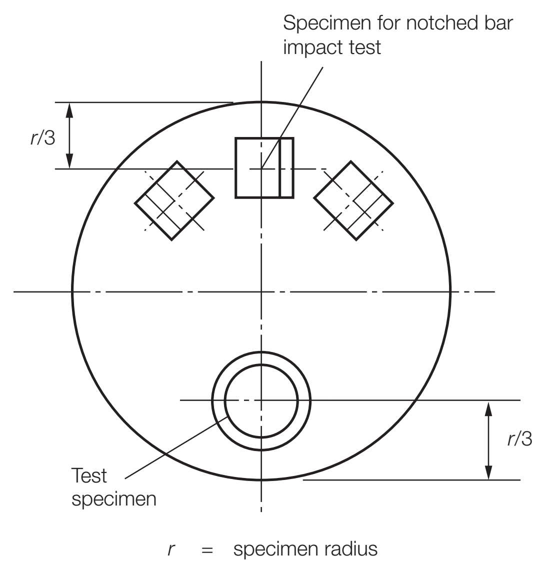


Fig. 3.9.1 Sampling of steel bars

9.6.2 For all grades, one tensile test is to be taken from each sample length selected. Additionally, for Grades U3, R3, R3S, R4, R4S and R5 material, one set of three Charpy V-notch impact test specimens is to be prepared. Impact tests are also required for Grade U2 when the chain is to be supplied in as-welded condition.

9.6.3 The results of all tensile and, where applicable, impact tests are to be in accordance with the appropriate requirements of Table 3.9.2.

9.6.4 Failure to meet the requirements will result in the rejection of a batch of material, unless it is clearly attributed to improper simulated heat treatment. This is to be confirmed to be to the satisfaction of LR, and further heat treatment and testing will be required prior to acceptance.

9.7 Structure and hardenability tests

9.7.1 For Grades R4S and R5, the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusion. These must be acceptable for the final product.
(b) Macro etching on a representative sample, in accordance with ASTM E381 or equivalent. This must be free from any injurious segregation or porosity.
(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

9.8 Dimensional tolerances

9.8.1 The tolerances on diameter and ovality of the bar are to be in accordance with Table 3.9.3.

9.9 Non-destructive examination

9.9.1 For the R3, R3S, R4, R4S and R5 grades all bars are to be inspected by a magnetic particle or eddy current method, and are also to be subjected to ultrasonic examination.

9.9.2 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

9.9.3 All non-destructive examination operators are to be qualified in the method of non-destructive examination, to a minimum of Level II in accordance with a recognised standard.

9.9.4 The bars are to be free from pipes, cracks, flakes, and injurious surface defects such as seams, laps, and rolled-in mill scale. Longitudinal discontinuities may be removed by blending to a smooth contour provided that their depth is not greater than 1 per cent of the bar diameter, and that the required diameter tolerances are not compromised. The contour radiuses are to be a minimum of four times the excavation depth.

9.9.5 The frequency of non-destructive testing may be reduced at the discretion of LR, provided statistical evidence is available that the required quality is achieved consistently.

Table 3.9.2 Mechanical properties

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests: Test temperature °C	Charpy V-notch impact tests: Average energy J minimum	Charpy V-notch impact tests: Average energy flash weld J minimum
U1	–	370–490	25	—	—	—	—
U2	295	490–690	22	—	0 (*see* Note 1)	27	—
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35	— —
R3	410 (*see* Note 3)	690 minimum (*see* Note 3)	17	50	0 –20 (*see* Note 2)	60 40	50 30
R3S	490 (*see* Note 3)	770 minimum (*see* Note 3)	15	50	0 –20 (*see* Note 2)	65 45	53 33
R4	580 (*see* Note 3)	860 minimum (*see* Note 3)	12	50	–20	50	36
Grade R4S (*see* Note 4)	700 (*see* Note 3)	960 minimum (*see* Note 3)	12	50	–20	56	40
Grade R5 (*see* Note 4)	760 (*see* Note 3)	1000 minimum (*see* Note 3)	12	50	–20	58	42

NOTES
1. Impact tests may be waived when the chain cable is to be supplied in one of the heat treated conditions given in Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C, at the option of LR.
3. The ratio of yield strength to tensile strength should not exceed 0,92.
4. The maximum hardness for R4S is to be HB330, and for R5 is to be HB340.

Table 3.9.3 Dimensional tolerance of bar stock

Nominal diameter mm	Tolerance on diameter mm	Tolerance on roundness ($d_{max} - d_{min}$) mm
≤20	–0/+1,0	0,60
>20 ≤25	–0/+1,0	0,60
>26 ≤35	–0/+1,2	0,80
>36 ≤50	–0/+1,6	1,10
>51 ≤80	–0/+2,0	1,50
>81 ≤100	–0/+2,6	1,95
>101 ≤120	–0/+3,0	2,25
>121 ≤160	–0/+4,0	3,00
>161 ≤210	–0/+5,0	4,00

9.10 Identification

9.10.1 Each bar is to be identified in accordance with 1.10 and, in addition, is to be marked with the appropriate grade of chain cable.

9.11 Certification of materials

9.11.1 Each consignment of bars is to be accompanied by a certificate of a type and in accordance with 1.11, but with the addition of the grade of chain cable, the rolling reduction ratio, the results of the micro inclusion, macro etch and hardenability tests, where required by each grade.

■ *Section 10* High strength quenched and tempered steels for welded structures

10.1 Scope

10.1.1 Provision is made in this Section for weldable high strength quenched and tempered steel plates and wide flats up to 70 mm thick. However, special consideration will be given to thicknesses up to 50 mm supplied in the TM rolled condition.

10.1.2 Plates and wide flats exceeding 70 mm in thickness as well as other product forms may also be supplied in accordance with the requirements of this Section, provided that the prior agreement of LR is obtained.

10.1.3 The steels may be supplied in six strength levels with minimum yield stresses of 420, 460, 500, 550, 620 and 690 N/mm^2 respectively.

10.1.4 Each strength level is sub-divided into four grades AH, DH, EH and FH, differing essentially in the required levels of notch toughness.

10.1.5 For the designation to fully identify a steel and its properties, the appropriate grade letter should precede the strength level number, e.g., EH 42.

10.1.6 Steels differing in strength level, mechanical properties and chemical composition from those detailed in this Section may be supplied, subject to special approval from LR. Such steels are to have the letter 'S' after the agreed identification mark.

10.2 Manufacture and chemical composition

10.2.1 The steels are to be fully killed and fine grain treated.

10.2.2 The chemical composition is to comply with the requirements of the approved manufacturing specification and the limits set in Table 3.10.1.

10.2.3 The cold cracking susceptibility, P_{cm}, may be used as an alternative to the carbon equivalent for evaluating weldability. It is to be calculated from the ladle analysis using the following formula:

$$P_{cm} = C + \frac{Si}{30} + \frac{Mn + Cr + Cu}{20} + \frac{Ni}{60} + \frac{Mo}{15} + \frac{V}{10} + 5B$$

The maximum allowable P_{cm} is to be agreed with LR and is to be included in the approved manufacturing specification.

10.3 Mechanical properties

10.3.1 At least one tensile test piece and one set of three Charpy V-notch impact tests specimens are to be taken from each piece as heat treated.

10.3.2 For continuously heat treated products, one tensile test piece and a set of three impact test specimens are to be taken from each plate as heat treated.

10.3.3 For plates and wide flats with widths exceeding 600 mm, the tensile and impact test specimens are to be taken with their axes transverse to the final direction of rolling. For other products, the impact test specimens are to be taken in the longitudinal direction but the tensile test specimens may be taken in either the longitudinal or transverse direction as agreed with LR.

10.3.4 The results of all tests are to comply with the appropriate requirements of Table 3.10.2.

10.3.5 Where standard subsidiary impact test specimens are necessary, *see* Ch 2,3.2.4.

Table 3.10.1 Chemical composition

Grade	AH	DH EH	FH
Carbon % max	0,21	0,20	0,18
Manganese % max	1,70	1,70	1,60
Silicon % max	0,55	0,55	0,55
Phosphorus % max	0,035	0,030	0,025
Sulphur % max	0,035	0,030	0,025
Nitrogen % max	0,020	0,020	0,020
Grain refining elements (*see* Note 1)			
Aluminium (acid soluble) % min (*see* Note 2)		0,015	
Niobium %		0,02—0,05	
Vanadium %		0,03—0,10	
Titanium % max		0,02	
Total (Nb + V + Ti) % max		0,12	

NOTES
1. The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the content is to be within the limits given in the Table. When used in combination, these limits are not applicable but the proportions of the grain refining elements are to be in accordance with the approved manufacturing specification.
2. The total aluminium content may be determined instead of the acid soluble content. In such cases the total aluminium content is not to be less than 0,020%.
3. Alloying elements and residual elements other than those listed in the Table (e.g., Ni, Cr, Cu, Mo and B) are to be included in the approved manufacturing specification.

10.4 Identification of materials

10.4.1 The particulars detailed in 1.10 are to be marked on each piece which has been accepted and, for ease of recognition, are to be encircled or otherwise marked with paint.

10.5 Certification of materials

10.5.1 At least two copies of each test certificate are to be provided. They are to be of the type and give the information detailed in 1.11 and, additionally, are to state the specified maximum carbon equivalent. As a minimum, chemical composition is to include the contents of any grain refining elements used and of the residual elements as detailed in Table 3.10.1.

Table 3.10.2 Mechanical properties for acceptance purposes

Grade	Yield stress N/mm² min. (*see* Note 1)	Tensile strength N/mm²	Elongation on $5,65\sqrt{S_o}$ % minimum (*see* Note 2)		Charpy V-notch impact tests (*see* Note 4)		
					Test temperature	Average energy J minimum	
			Transverse	Longitudinal	°C	Transverse	Longitudinal
AH 42 DH 42 EH 42 FH 42	420	530 – 680	18	20	0 –20 –40 –60	28	42
AH 46 DH 46 EH 46 FH 46	460	570 – 720	17	19	0 –20 –40 –60	31	46
AH 50 DH 50 EH 50 FH 50	500	610 – 770	16	18	0 –20 –40 –60	33	50
AH 55 DH 55 EH 55 FH 55	550	670 – 830	16	18	0 –20 –40 –60	37	55
AH 62 DH 62 EH 62 FH 62	620	720 – 890	15	17	0 –20 –40 –60	41	62
AH 69 DH 69 EH 69 FH 69	690	770 – 940	14	16	0 –20 –40 –60	46	69

NOTES

1. Where a distinct yield stress indication is not obtainable during tensile testing the 0,2% proof stress is applicable.
2. For full thickness tensile test specimens with a width of 25 mm and a gauge length of 200 mm (*see* Fig. 2.2.4 in Chapter 2) the minimum elongation is to be:

Thickness mm		≤10	>10 ≤15	>15 ≤20	>20 ≤25	>25 ≤40	>40 ≤50	>50 ≤70
Strength levels								
Elongation %	42	11	13	14	15	16	17	18
	46	11	12	13	14	15	16	17
	50 and 55	10	11	12	13	14	16	16
	62	9	11	12	12	13	14	15
	69	9	10	11	11	12	13	14

These values apply to transverse specimens. Where the use of longitudinal specimens has been agreed, the values are to be increased by 2%.

3. The ratio of yield strength to tensile strength should not exceed 0,94.
4. Impact tests are not required on thicknesses less than 6 mm.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Castings are to be made at foundries approved by LR. The steel used is to be manufactured by a process approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 All flame cutting, scarfing or arc-air gouging to remove surplus metal is to be undertaken in accordance with recognised good practice and is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the chemical composition and/or thickness of the casting. The affected areas are to be either machined or ground smooth for a depth of about 2 mm unless it has been shown that the material has not been damaged by the cutting process. Special examination will be required to find any cracking in way of the cut surfaces.

1.2.3 Where two or more castings are joined by welding to form a composite item, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests will be required*, see also* the requirements of 1.9.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved specification.

1.3.2 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.3.3 The locations of all chaplets are to be noted and to be subject to close visual inspection (and when necessary ultrasonic examination) to ensure complete fusion.

1.4 Chemical composition

1.4.1 All castings are to be made from killed steel. The chemical composition of the ladle sample is to be within the limits given in the relevant Section of this Chapter. Where general overall limits are specified, the chemical composition is to be appropriate for the type of steel, dimensions and required mechanical properties of the castings.

1.4.2 Except where otherwise specified, suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.5 Heat treatment

1.5.1 All castings are to be heat treated in accordance with the requirements given in the relevant Section of this Chapter.

1.5.2 Heat treatment is to be carried out in a properly constructed furnace which is efficiently maintained and has adequate means of temperature control and is fitted with pyrometers which measure and record the temperature of the furnace charge. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. Sufficient thermocouples are to be connected to the furnace charge to show that its temperature is adequately uniform and the temperatures are to be recorded throughout the heat treatment. Alternative procedures are to be approved by LR, Materials and NDE department. Copies of these records are to be presented to the Surveyor together with a sketch showing the positions at which the temperature measurements were carried out. The records are to identify the furnace that was used and give details of the charge, the heat treatment temperature and time at temperature and the date. The Surveyor is to examine the charts and confirm the details on the certificate. In the case of very large components which require heat treatment, alternative methods will be specially considered.

1.5.3 If a casting is locally reheated, or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required in order to avoid the possibility of harmful residual stresses.

1.6 Test material and test specimens

1.6.1 Test material sufficient for the tests specified in Sections 2 to 9 and for possible re-test purposes is to be provided for each casting. The test samples are to be either integrally cast or gated to the casting and are to have a thickness of not less than 30 mm.

1.6.2 The test samples are not to be detached from the casting until the heat treatment specified in 1.5.1 has been completed and they have been properly identified.

1.6.3 As an alternative to 1.6.1 and 1.6.2, where a number of small castings of about the same size, each of which is under 1000 kg in mass, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted, using separately cast test samples of suitable dimensions. The test samples are to be properly identified and heat treated together with the castings which they represent. At least one test sample is to be provided for each batch of castings.

1.6.4 The test specimens are to be prepared in accordance with the requirements of Chapter 2. Tensile test specimens are to have a cross-sectional area of not less than 150 mm^2.

1.6.5 Re-test procedures are to be in accordance with Ch 2,1.4.

1.7 Visual and non-destructive examination

1.7.1 This Section gives the general requirements for non-destructive examination of steel castings. As an alternative, castings may be examined in accordance with a National Specification, provided it gives reasonable equivalence to these Rules.

1.7.2 All castings are to be cleaned and adequately prepared for inspection. Suitable methods include pickling, caustic cleaning, wire brushing, local grinding, shot or sand blasting.

1.7.3 The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.7.4 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.7.5 All castings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces. Castings are to be subject to magnetic particle examination or dye penetrant inspection (for austenitic stainless steel castings, *see* Section 8) in accordance with 1.7.9, unless more specific requirements for non-destrutive examination are included in subsequent Sections of this Chapter, other parts of the Rules or the agreed specification.

1.7.6 Where specified or required by the Rules non-destructive examination is to be carried out before acceptance. All tests are to be in accordance with the requirements of Ch 1,5.

1.7.7 The manufacturer is to provide the Surveyor with a signed report confirming that non-destructive examination has been carried out and that such inspection has not revealed any significant defects.

1.7.8 Where magnetic particle examination is specified or required, this is to be carried out using a suspension of magnetic particles in a suitable fluid. The dry powder method is not acceptable for the final inspection. Prods are not permitted on finished machined surfaces.

1.7.9 Where required, magnetic particle or dye penetrant testing is to be carried out by the manufacturer whenever appropriate and also when the castings are in the finished condition. The tests are to be made in the presence of the Surveyor unless otherwise specially agreed. The castings are to be examined in the following areas:
(a) At all accessible fillets and changes of section.
(b) At positions where surplus metal has been removed by flame cutting, scarfing or arc-air gouging.
(c) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(d) In way of welds.
(e) In way of chaplets.
(f) At other positions agreed with the Surveyor to include areas which may be subjected to high stress in service.

1.7.10 Where required by subsequent Sections or by the agreed specification, ultrasonic examination is to be carried out by the manufacturer, but Surveyors may request to be present in order to verify that the examination is carried out in accordance with the agreed procedure. This examination is to be carried out in the following areas:

(a) At positions which may be subjected to high stresses in service, as agreed with the Surveyor.
(b) In way of fabrication weld preparations, for a distance not less than 50 mm form the edge.
(c) At positions where subsequent machining may expose filamentary shrinkage or other defects (e.g., bolt holes, bearing bores).
(d) In way of welding.
(e) In way of riser positions.
(f) At positions where experience shows that significant internal defects may occur: these are to be agreed between the manufacturer and the Surveyor.

1.7.11 Radiographic examination, where required, is to be carried out by the manufacturer in areas generally as indicated for ultrasonic examination in 1.7.10. All radiographs are to be submitted to the Surveyor for examination and acceptance. The radiographic technique and acceptance standards are to be to the satisfaction of the Surveyor and in accordance with any requirements of the approved specification.

1.7.12 In the event of any casting proving to be defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.7.13 The general acceptance criteria given in 2.5.2 are to be applied where no specific acceptance criteria are stated in the subsequent Sections of this Chapter.

1.8 Pressure testing

1.8.1 Where required by the relevant Rules, castings are to be pressure tested in the final machined condition before final acceptance. These tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

1.9 Rectification and dressing of castings

1.9.1 When unacceptable defects are found in a casting, these are to be removed by machining or chipping. Flame-scarfing or arc-air gouging may also be used provided that preheating is employed when necessary and that the surfaces of the resulting excavation are subsequently ground smooth. Complete elimination of the defective material is to be proven by adequate non-destructive examination. Shallow grooves or excavations resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding. Complete elimination of the defective material is to be verified by magnetic particle or dye penetrant testing.

1.9.2 Where flame scarfing or arc-air gouging is used, the requirements detailed in 1.2.2 are to apply.

1.9.3 Grinding wheels for use on austenitic stainless steels are to be of an iron-free type and shall have been used only on stainless steels.

1.9.4 All proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to satisfy himself that the number, position and size of the defects are such that the casting can be effectively repaired.

1.9.5 A statement and/or sketch detailing the extent and position of all welds is to be prepared by the manufacturer. Copies of these sketches are to be submitted to LR, and copies are to be attached to the certificates for the castings.

1.9.6 All welding is to be carried out by an approved welder and in accordance with an approved welding procedure which includes the features referred to in 1.9.6 to 1.9.13.

1.9.7 Where welding is required, a grain refining heat treatment is to be given to the whole casting prior to carrying out welding unless agreed otherwise with the Surveyor. Grain refining heat treatment requires heating above the upper critical temperature.

1.9.8 Any excavations are to be of suitable shape to allow good access for welding and, after final preparation for welding, are to be re-examined by suitable non-destructive testing methods to ensure that all defective material has been eliminated.

1.9.9 All castings in alloy steels other than austenitic and duplex stainless steels are to be suitably preheated prior to welding. Castings in carbon-manganese steels may also be required to be preheated, depending on their chemical composition, the dimensions, configuration and positions of the welds.

1.9.10 Welding is to be carried out under cover, in positions free from draughts and adverse weather conditions. As far as possible, all welding is to be carried out in the downhand (flat) position.

1.9.11 The welding consumables used are to be of an appropriate composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. The use of low hydrogen type welding consumables is preferred. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 1.9.12, and the results of these tests are to be presented to the Surveyor.

1.9.12 After welding is completed, the castings are to be given the heat treatment specified in Sections 2 to 9, or a stress relieving heat treatment at a temperature of not less than 550°C. The type of heat treatment required will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs.

1.9.13 Special consideration may be given to a local stress relieving heat treatment. where both the welded area is small and machining of the casting has reached an advanced stage, prior agreement is to be obtained from LR in writing. The welding procedure is to be such that residual stresses are minimised.

1.9.14 On completion of heat treatment, all welds and adjacent material are to be ground smooth and examined by magnetic particle, or liquid penetrant testing, ultrasonic or radiographic examination. The Surveyor is to attend at these inspections, to witness the results of magnetic particle or liquid penetrant examination and to examine any radiographs. Satisfactory results are to be obtained from all forms of non-destructive examination used.The acceptance criteria for the NDE of welds are to be in accordance with subsequent Sections of this Chapter or where these do not exist, Tables 13.2.4 to 13.2.6 in Chapter 13, as appropriate.

1.9.15 Where no welding has been made on a casting, the manufacturer is to provide the Surveyor with a written statement that this is the case.

1.9.16 The foundry is to maintain full records detailing the weld procedure, heat treatment and the extent and location of all welds made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.9.17 For rectification of defective steel castings for crankshafts, *see* 4.7.

1.10 Identification of castings

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities to trace the castings when required.

1.10.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(b) Manufacturer's name or trade mark.
(c) LR or Lloyd's Register and the abbreviated name of LR's local office.
(d) Personal stamp of Surveyor responsible for inspection.
(e) Test pressure, where applicable.
(f) Date of final inspection.

1.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and steel grade.
(c) Identification number.
(d) Steel making process, cast number, chemical analysis of ladle samples and, in the case of the Special grade (*see* Section 2), the chemical analysis of the product or test bar.
(e) General details of heat treatment including the temperature and time at temperature.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 Where applicable, the manufacturer is to provide a signed report regarding non-destructive examination as required by 1.7.7 together with a statement and/or sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.5 or the statement detailed in 1.9.15.

■ *Section 2* Castings for ship and other structural applications

2.1 Scope

2.1.1 The requirements for carbon-manganese steel castings, intended for ship and other structural applications where the design and acceptance tests are related to mechanical properties at ambient temperature, are given in this Section.

2.1.2 Provision is made for two quality grades, Normal and Special.

2.1.3 Where it is proposed to use carbon-manganese steels of higher specified minimum tensile strength than required by 2.4.3, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

2.2 Chemical composition

2.2.1 The chemical composition of ladle samples is to comply with Table 4.2.1.

2.2.2 For the Special grade, the product of the aluminium and nitrogen contents is to comply with the following formula:

$$(\%\ Al_{acid\ sol} \times \%\ N)\ 10^5 \leq 60$$

2.2.3 For the Special grade, a check chemical analysis on the product or a test bar is mandatory. The check analysis on the product or test bar is to comply with the requirements of Table 4.2.1.

Table 4.2.1 Chemical composition

Quality grade	Normal	Special (*see* Note 3)
Carbon	0,23% max.	0,23% max.
Silicon	0,60% max.	0,60% max.
Manganese	0,70–1,60%	0,70–1,60%
Sulphur	0,040% max.	0,035% max.
Phosphorus	0,040% max.	0,035% max.
Aluminium – (acid soluble)	—	0,015–0,080% (*see* Notes 1 and 2)
Residual elements:		
Copper	0,30% max.	0,30% max.
Chromium	0,30% max.	0,30% max.
Nickel	0,40% max.	0,40% max.
Molybdenum	0,15% max.	0,15% max.
Total	0,80% max.	0,80% max.

NOTES
1. The total aluminium content may be determined instead of the acid soluble content, in which case the total aluminium content is to be 0,020–0,10%.
2. Grain refining elements other than aluminium may be used subject to special agreement with LR.
3. For the Special grade, the nitrogen content is to be determined.

2.3 Heat treatment

2.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

2.3.2 For larger castings where a coarse of microstructure may be present in heavier thickness, a double austenising heat treatment may be required to ensure adequate grain refinement. A coarse microstructure will be indicated by an increased attenuation of approxiamtely 30 dB/m at 2 MHz during ultrasonic examination.

2.3.3 Following weld repair and or the attachment of handling brackets, all castings are to be subject to post weld heat treatment at a temperature of not less than 550°C before delivery.

2.4 Mechanical tests

2.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

2.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

2.4.3 The results of these tests are to comply with the following requirements:

Yield stress	200 N/mm^2 min.
Tensile strength	400 N/mm^2 min.
Elongation on $5{,}65\sqrt{S_o}$	25% min.
Reduction of area	40% min.

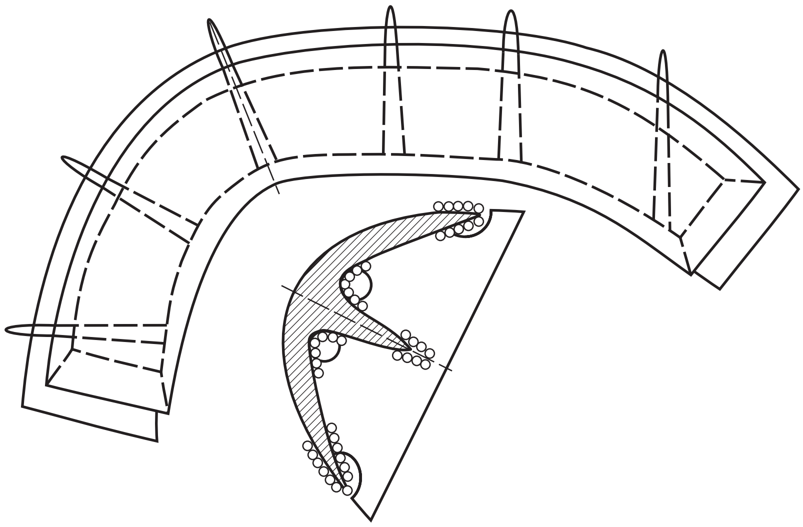
2.4.4 A set of three Charpy V-notch impact test specimens is to be provided with each casting in the Special grade. These may be taken from a small extension of the thickest part of the casting or from a block cast integrally with the casting and having dimensions representative of the largest section thickness of the casting. These are to be tested in accordance with Chapter 2 and are to have an average energy of not less than 27J at 0°C.

2.5 Non-destructive examination

2.5.1 Castings used in ship construction for the sternframe, rudder and propeller shaft supports are to be examined by ultrasonic and magnetic particle methods in accordance with 1.7. The type and extent of non-destructive examination of castings for other structural applications are to be specially agreed by the Surveyor.

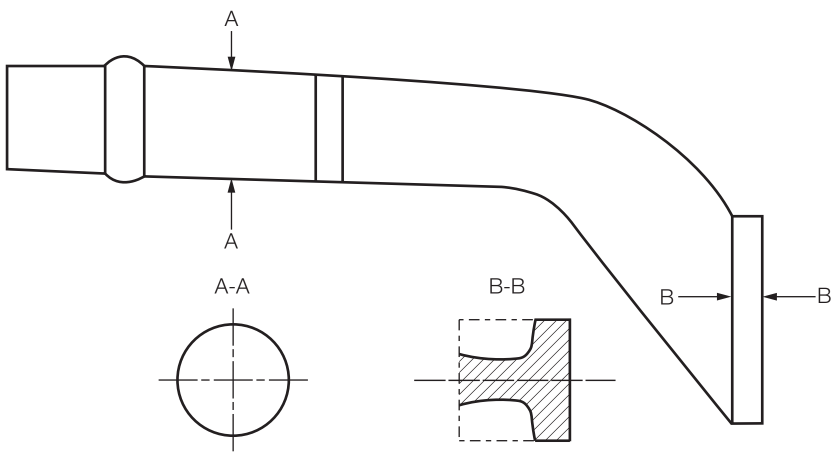
2.5.2 The extent and methods of non-destructive examination to be applied to typical hull steel castings are shown in Figs. 4.2.1 to 4.2.6 in addition to the areas specified in 1.7.9 and 1.7.10.

2.5.3 Acceptance levels for Visual Inspection are to be taken as follows:
(a) No cracks or hot tears are permitted.
(b) Castings are to be free of other injurious indications to the satisfaction of the Surveyor.
(c) Additional magnetic particle, dye penetrant or ultrasonic testing may be required for a more detailed evaluation of surface irregularities at the request of the Surveyor. These examinations are in addition to those required by 2.6.



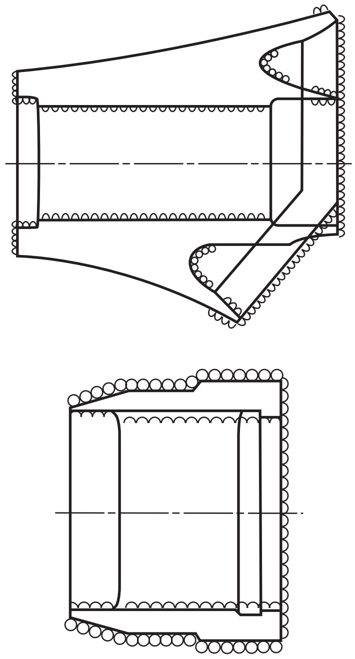
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing

Fig. 4.2.1 Extent of non-destructive evaluation for stern frame castings



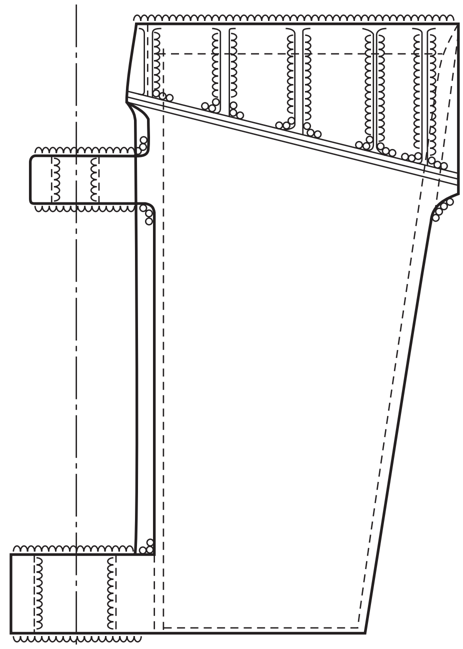
Location of non-destructive examination
All surfaces: Visual examination
Magnetic particle and ultrasonic testing

Fig. 4.2.2 Extent of non-destructive evaluation for rudder stock castings



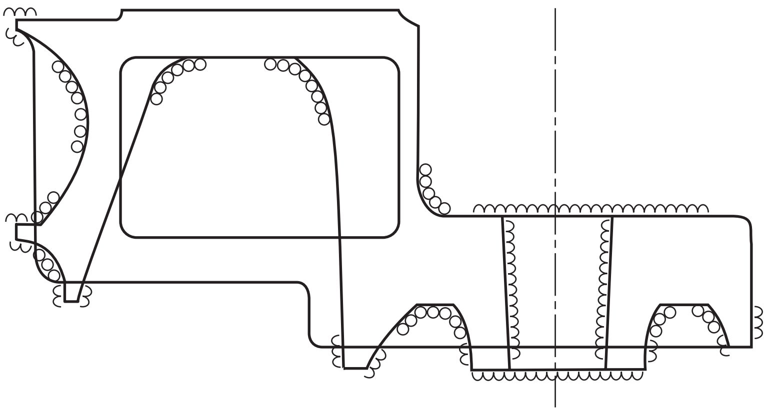
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and ultrasonic testing
3. Location indicated with ( ): Ultrasonic testing

Fig. 4.2.3
Extent of non-destructive evaluation for stern boss castings



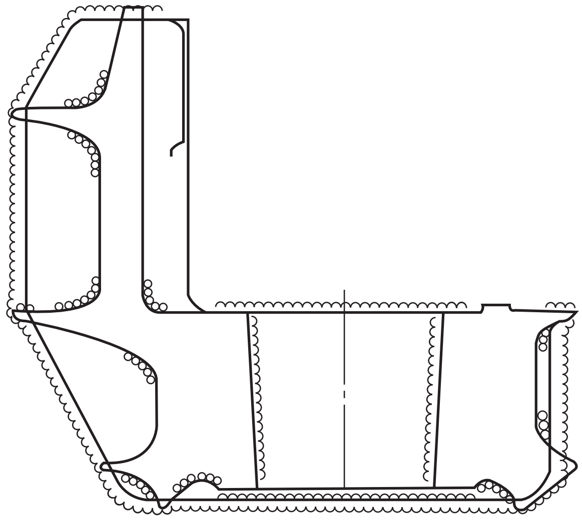
Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with ( ): Ultrasonic testing

Fig. 4.2.4
Extent of non-destructive evaluation for rudder hanging castings



Location of non-destructive examination
1. All surfaces: Visual examination
2. Location indicated with (ooo): Magnetic particle and Ultrasonic testing
3. Location indicated with ( ): Ultrasonic testing

Fig. 4.2.5 Extent of non-destructive evaluation for rudder (upper part) castings



Location of non-destructive examination

1.	All surfaces:	Visual examination
2.	Location indicated with (ooo):	Magnetic particle and Ultrasonic testing
3.	Location indicated with (ᴗᴗᴗ):	Ultrasonic testing

Fig. 4.2.6
Extent of non-destructive evaluation for rudder (lower part) castings

2.6 Acceptance levels for surface crack detection

2.6.1 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Non-linear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less, edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles, or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles, or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

2.6.2 For the purpose of evaluating indications, the surface is to be divided into reference band length of 150 mm for level MT1/PT1 and into reference areas of 225 cm^2 for level MT2/PT2. The band length and/or area is to be taken in the most unfavourable location, relative to the indications being evaluated.

2.6.3 The following quality levels recommended for magnetic particle testing (MT) and/or dye penetrant testing (PT) are;
(a) Level MT1/PT1 – fabrication weld preparation areas.
(b) Level MT2/PT2 – other locations indicated on Figs. 4.2.1 to 4.2.6.
The acceptance criteria are shown in Table 4.2.2. Cracks and hot tears are not acceptable.

2.6.4 Acceptance criteria for ultrasonic testing are shown in Table 4.2.3 as UT1 and UT2. Discontinuities within the examined zones interpreted to be cracks or hot tears, are not acceptable.

2.6.5 Level UT1 is applicable to the following:
(a) Fabrication weld preparations for a distance of 50 mm.
(b) 50 mm depth from the final machined surface including boltholes.
(c) Fillet radii to a depth of 50 mm and within a distance of 50 mm from the radius end.
(d) Castings subject to cyclic bending stresses, e.g., rudder horn, rudder castings and rudder stocks, the outer one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6

2.6.6 Level UT2 is applicable to the following:
(a) For locations which are not specified in 2.6.5, nominated for ultrasonic testing in Figs. 4.2.1 to 4.2.6 or on the inspection plan.
(b) Positions outside locations nominated for level UT1 examination where feeders and gates have been removed.
(c) Castings subject to cyclic bending stresses, at the central one third of thickness in the zones shown in Figs. 4.2.1 to 4.2.6.

Table 4.2.2 Acceptance criteria for surface inspection evaluation

Quality level	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm (*see* Note 2)
MT1/PT1	4 in 150 mm length	Non-linear Linear Aligned	4, *see* Note 1 4, *see* Note 1 4, *see* Note 1	5 3 3
MT2/PT2	20 in 22500 mm^2 area	Non-Linear Linear Aligned	10 6 6	7 5 5

NOTES
1. Minimum of 30 mm between relevant indications.
2. In weld repairs, the maximum dimension is 2 mm.

Table 4.2.3 Ultrasonic acceptance criteria for marine steel castings

Quality level	Allowable disc shape according to the Distance-Gain Size (DGS), mm	Maximum number of indications to be registered, *see* Note 1	Allowable length of linear indications, mm, *see* Note 2
UT1	>6	0	0
UT2	12–15 >15	5 0	50 0

NOTES
1. Grouped in an area measuring 300 x 300 mm.
2. Measured on the scanning surface.

2.6.7 Ultrasonic acceptance criteria for casting areas not nominated in Figs. 4.2.1 to 4.2.6 will be subject to special consideration, based on the anticipated stress levels and the type, size and position of the discontinuity.

2.6.8 Parts which are welded are to be examined by the same method as at the initial inspection as well as by additional methods as required by the Surveyor.

■ *Section 3* Castings for machinery construction

3.1 Scope

3.1.1 This Section gives the material requirements for carbon-manganese steel castings intended for use in machinery construction and which are not within the scope of Sections 4 to 7.

3.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 3.2.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval.

3.1.3 The manufacture or repair of cast steel connecting rods is not permitted, except where the manufacturing and quality control procedures have been approved by LR. For approval purposes, tests are to be carried out at the place of manufacture using the proposed process to demonstrate that the castings are sound. Tests are to be carried out to confirm that the appropriate mechanical properties are attained within the casting, including areas where weld repairs have been performed. Any changes to manufacturing, repair and quality control procedures are to be submitted to LR for approval, *see also* Ch 1,2.2.

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples is to comply with the following limits, except as specified in 3.2.2:

Carbon	0,40% max.
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

3.2.2 Castings which are intended for parts of a welded fabrication are to be of weldable quality with a carbon content generally not exceeding 0,23 per cent.

3.2.3 Proposals to use steels with higher carbon content, or alloy steels, for welded construction will be subject to special consideration.

3.3 Heat treatment

3.3.1 Castings are to be supplied:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C; or
(d) quenched and tempered at a temperature of not less than 550°C.

3.3.2 Engine bedplate castings, turbine castings and any other castings where dimensional stability and freedom from internal stresses are important, are to be given a stress relief heat treatment. This is to be at a temperature not lower than 550°C, followed by furnace cooling to 300°C or lower. Alternatively, full annealing may be used provided that the castings are furnace cooled to 300°C or lower.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on material representing each casting or batch of castings.

3.4.2 Where the casting is of complex design, or where the finished mass exceeds 10 tonnes, two test samples are to be provided. Where large castings are made from two or more casts which are not mixed in a ladle prior to pouring, two or more test samples are required corresponding to the number of casts involved. The test samples are to be integrally cast at locations as widely separated as possible.

3.4.3 Table 4.3.1 gives the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate levels of minimum tensile strength may be specified, in which case minimum values for yield stress, elongation and reduction of area may be obtained by interpolation.

Table 4.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel castings for machinery construction

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum
400–550	200	25	40
440–590	220	22	30
480–630	240	20	27
520–670	260	18	25
560–710	300	15	20
600–750	320	13	20

3.4.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.3.1.

3.4.5 The results of all tensile tests are to comply with the requirements of Table 4.3.1 appropriate to the specified minimum tensile strength.

3.4.6 For alloy steel castings and carbon-manganese steel castings containing more than 0,40 per cent carbon, the results of all mechanical tests are to comply with an approved specification.

3.4.7 When a casting, or a batch of castings, has failed to meet the mechanical test requirements, it may be re-heat treated and re-submitted for acceptance tests but this may not be carried out more than twice, *see* Ch 1,4.6.

3.5 Non-destructive examination

3.5.1 All piston crowns and cylinder covers are to be examined by ultrasonic testing. In addition, where these castings are intended for engines having a bore size larger than 400 mm, they are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.2 Engine bedplate castings are to be examined by ultrasonic and magnetic particle or dye penetrant testing in accordance with 1.7.

3.5.3 Turbine castings are to be examined by magnetic particle or dye penetrant testing in accordance with 1.7. In addition, an ultrasonic or radiographic examination is to be made in way of fabrication weld preparations.

3.5.4 Other castings are to be examined by non-destructive methods where specified.

■ *Section 4*
Castings for crankshafts

4.1 Scope

4.1.1 This Section gives the requirements for carbon and carbon-manganese steel castings for semi-built crankshafts.

4.1.2 Where it is proposed to use steels of higher carbon content than is indicated in 4.3.1, or alloy steels, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For alloy steels, the specified minimum tensile strength is not to exceed 700 N/mm^2.

4.2 Manufacture

4.2.1 The method of producing combined web and pin castings is to be approved. For this purpose, tests to demonstrate the soundness of the casting and the properties at important locations may be required.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with the following limits:

Carbon	0,40% max. (*but see* 4.7.4(c))
Silicon	0,60% max.
Manganese	0,50–1,60%
Sulphur	0,040% max.
Phosphorus	0,040% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Nickel	0,40% max.
Molybdenum	0,15% max.
	Total 0,80% max.

4.4 Heat treatment

4.4.1 Castings are to be supplied either:

(a) fully annealed and cooled in the furnace to a temperature of 300°C or lower; or

(b) normalised and tempered at a temperature of not less than 550°C, and cooled in the furnace to a temperature of 300°C or lower.

4.5 Mechanical tests

4.5.1 Proposals for the number of tests and the location of test material on the casting are to be submitted by the manufacturer.

4.5.2 Not less than one tensile test and three impact tests are to be made on material representing each casting. The impact tests are to be carried out at ambient temperature.

4.5.3 Table 4.4.1 gives the minimum requirements for yield stress and elongation corresponding to different strength levels, and it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2 to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 4.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel castings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests average energy J minimum (*see* Note)
400–550	200	28	45	32
440–590	220	26	45	28
480–630	240	24	40	25
520–670	260	22	40	20
550–700	275	20	35	18

NOTE
Impact tests are to be made at ambient temperature.

4.5.4 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 4.4.1.

4.5.5 The results of all tests are to comply with the requirements of Table 4.4.1 appropriate to the specified minimum tensile strength. For the impact tests, one individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 1,4.6 for re-test procedures.

4.6 Non-destructive examination

4.6.1 Magnetic particle examination is to be carried out over all surfaces in accordance with Fig. 4.4.1.

4.6.2 Each casting is to be examined by ultrasonic testing, and the extent of examination and defect acceptance criteria, using the DGS (Distance Gain Size) technique, are to be as shown in Fig. 4.4.2. Alternative ultrasonic procedures may be submitted for approval.

4.7 Rectification of defective castings

4.7.1 The requirements of 1.9 apply, except where amended by this Section.

4.7.2 Where castings have shallow surface defects, consideration is first to be given to removing such defects by grinding and blending or by machining the surface where there is excess metal on the Rule dimension.

4.7.3 Subject to prior agreement and submission of the detailed welding procedure for approval by LR, welding may be carried out prior to the final austenitising heat treatment.

4.7.4 Approval for welding will not be given in the following circumstances:
(a) For the rectification of repetitive defects caused by improper foundry technique or practice.
(b) For the building up by welding of surfaces or large shallow depressions.
(c) Where the carbon content of the steel exceeds 0,30 per cent.
(d) Where the carbon equivalent of the steel, given by $C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15}$ exceeds 0,65 per cent.

4.7.5 Provided that the Surveyors are satisfied that welding is justified, they may also authorise welding to the surfaces of crankwebs, following the final austenitising heat treatment, within the following limits:
(a) In general, the volume of the largest groove which is to be welded is not to exceed 3,2t cm^3, where t is the web axial thickness, in cm. The total volume of all grooves which are to be welded is not to exceed 9,6t cm^3 per crankweb.
(b) The welds do not extend within the cross-hatched zones marked on Fig. 4.4.3 for semi-built crank throws.
(c) Larger welds on balance weights may be permitted at the discretion of the Surveyor, provided that such repairs are wholly contained within the balance weight and do not affect the strength of the crankweb.

4.7.6 Subsequent to the final austenitising heat treatment, welding may be authorised in the surface of the bore for the journal (or pin) within the following limits:
(a) In general, the welds are to be not less than 125 mm apart.
(b) The welds are not to be located within circumferential bands of $\frac{t}{5}$ from the edges of the bores, nor at any position within the inner 120° arc of the bores, as cross-hatched on Fig. 4.4.3.
(c) The volume of the largest weld is to be not more than 1,1t cm^3, where t is the web axial thickness at the bore, in cm, and not more than three welds are to be made in any one bore surface.

4.7.7 After all defective material has been removed from a region, and this has been proven in the presence of the Surveyor by magnetic particle inspection or other suitable method, the excavation is to be suitably shaped to allow good access for welding.

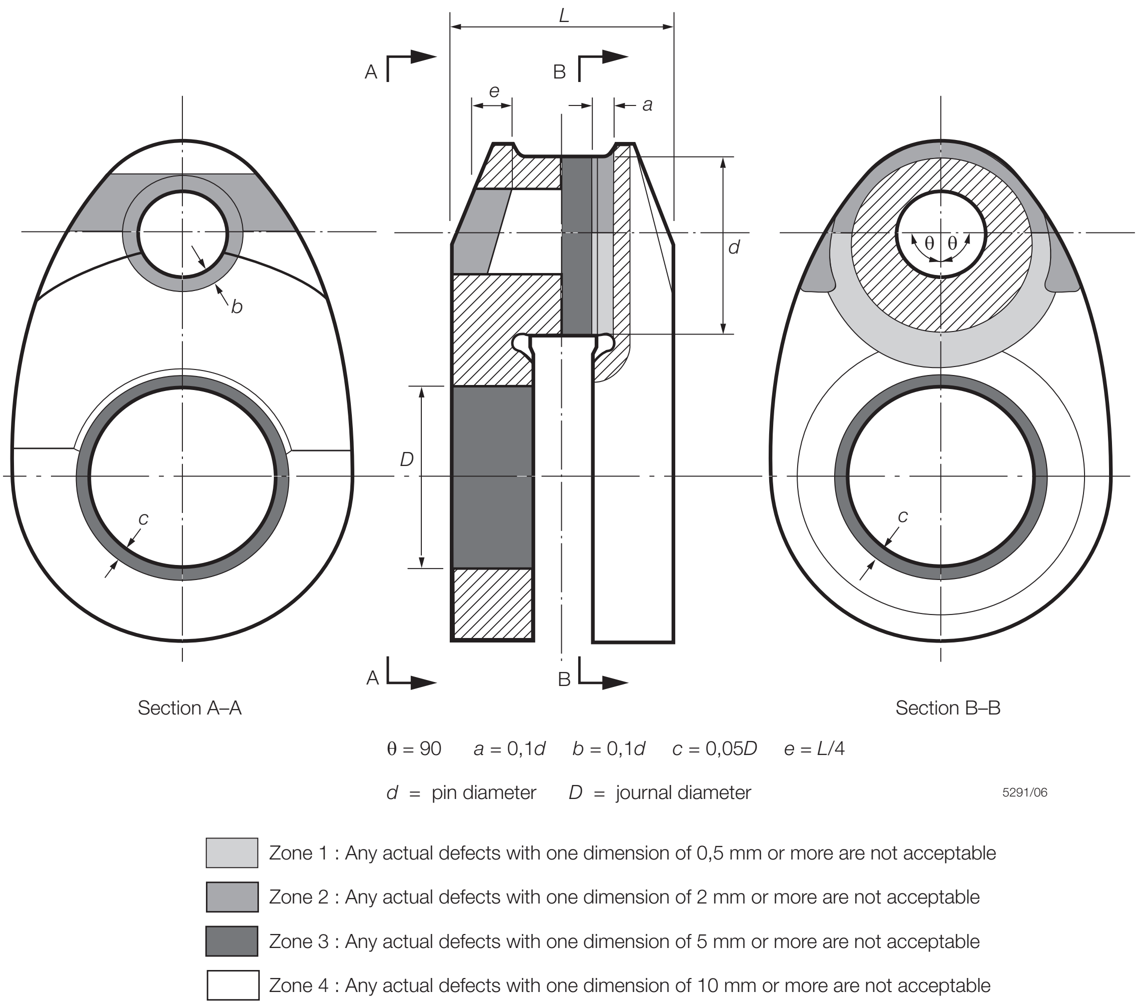


Fig. 4.4.1 Magnetic particle inspection acceptance levels

4.7.8 At the discretion of the Surveyor, the size of a groove may be increased beyond the limiting sizes given in 4.7.5 or 4.7.6, if the removal of further metal will facilitate welding.

4.7.9 Welding is to be carried out by approved welders using approved procedures. The welds are to be made by an electric arc process using low hydrogen type consumables which will produce a deposited metal that is not inferior in properties to the parent metal.

4.7.10 All castings are to be given a preliminary refining heat treatment prior to the commencement of welding. Before welding, the material is to be preheated in accordance with the qualified procedure. Where possible, preheating is to be carried out in a furnace. The preheat temperature is to be maintained until welding is completed, and preferably until the casting is charged to the furnace for post-weld heat treatment.

4.7.11 Where welding is carried out after the final austenitising heat treatments, a post-weld stress relieving heat treatment is to be applied at a temperature of not less than 600ºC, *see also* 1.5.2.

4.7.12 Welds are to be dressed smooth by grinding. The surfaces of the welds and adjacent parent steel are to be proven by magnetic particle and, where appropriate, ultrasonic inspection, *see* 1.9.15 and 1.9.14.

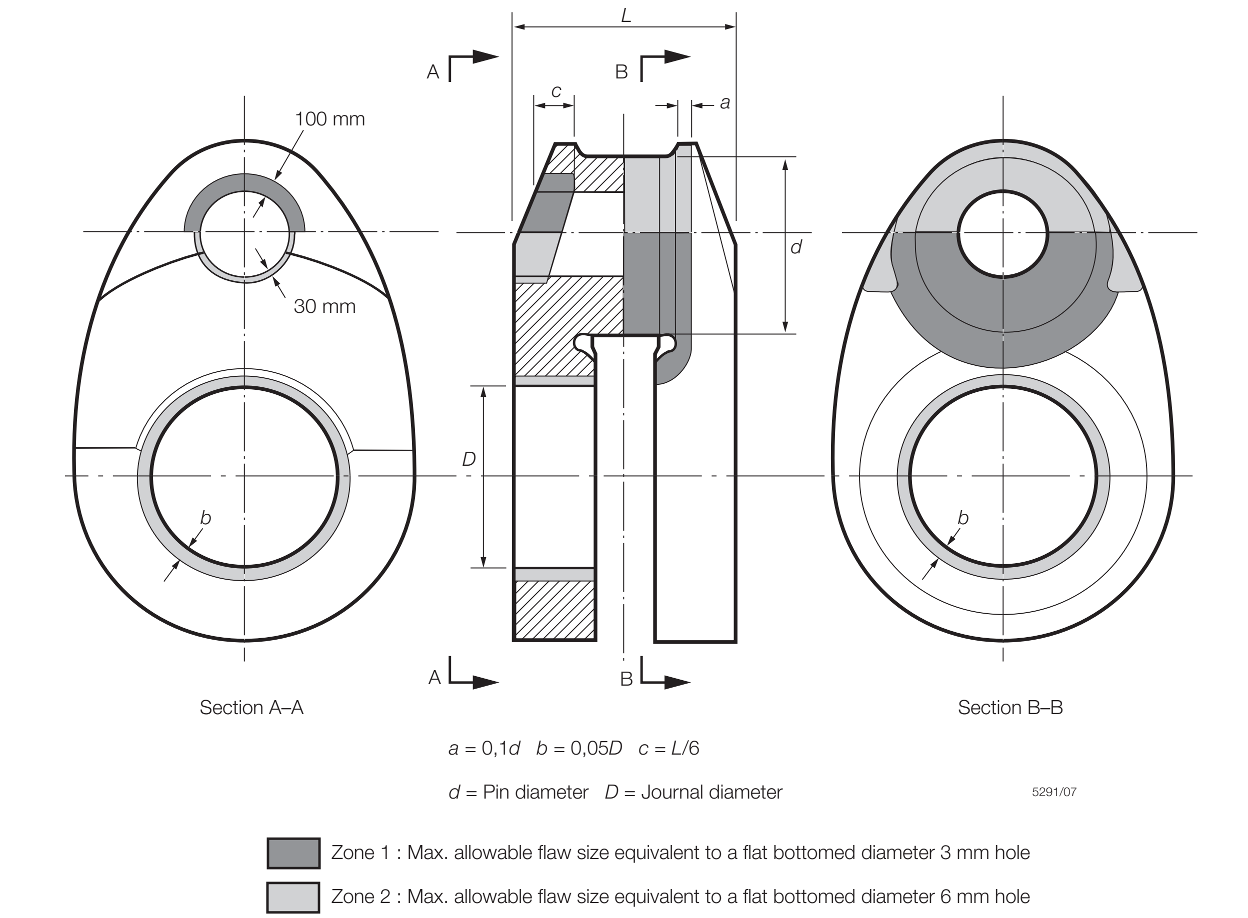


Fig. 4.4.2 Ultrasonic examination acceptance levels

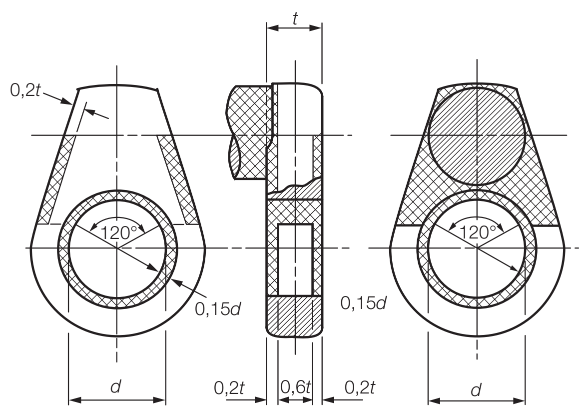


Fig. 4.4.3
Areas of semi-built crank throws to which weld repairs are not permitted

■ *Section 5*
Castings for propellers

5.1 Scope

5.1.1 This Section gives the requirements for steel castings for one-piece propellers and separately cast blades and hubs for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers, azipods and azimuth thrusters. The requirements for copper alloy propellers, blades and hubs are given in Ch 9,1.

5.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and Ch 4,1 as well as the requirements of this Section.

5.1.3 Full details of the manufacturer's specification are to be submitted for approval. These should include the chemical composition, heat treatment, mechanical properties, micro-structure and repair procedures.

5.1.4 Special requirements are given for castings which are intended for ice service in Table 4.5.2.

5.2 Chemical composition

5.2.1 The chemical composition of ladle samples is to comply with the approved specification, *see* 5.1.3.

5.2.2 Typical cast steel propeller alloys are given in Table 4.5.1.

5.3 Heat treatment

5.3.1 Martensitic stainless steel castings are to be austenitised, quenched and tempered in accordance with the approved specification, *see* 5.1.3.

5.3.2 Austenitic stainless steel castings are to be solution treated in accordance with the approved specification, *see* 5.1.3.

5.4 Mechanical tests

5.4.1 The test material is to be cast integral with the boss of propeller castings, or with the flange of separately cast propeller blades. Alternatively, the test material may be attached on blades in an area between 0,5 and 0,6*R*, where *R* is the radius of the propeller.

5.4.2 The test material is not to be removed from the casting until final heat treatment has been carried out. Removal is to be by non-thermal procedures.

5.4.3 At least one tensile test and for the martensitic stainless steel grades one set of three Charpy V-notch impact tests are to be made on material representing each casting. The results are to comply with the requirements of Table 4.5.2 or the approved specification.

5.4.4 As an alternative to 5.4.3, where a number of small propeller castings of about the same size, and less than 1 m in diameter, are made from one cast and heat treated in the same furnace charge, a batch testing procedure may be adopted using separately cast test samples of suitable dimensions. At least one set of mechanical tests is to be provided for each multiple of five castings in the batch.

5.4.5 Separately cast test bars may be used subject to prior approval of the Surveyor. Test bars must be cast from the same heat, or heats, and must also be heat treated with castings they represent.

5.5 Non-destructive examination

5.5.1 On completion of machining and grinding, the whole surface of each casting is to be examined in accordance with Ch 9,1.8.

5.5.2 When appropriate, magnetic particle inspection may be used in lieu of liquid penetrant testing.

5.5.3 Castings are to be free from cracks and hot tears.

Table 4.5.1 Typical chemical composition for steel propeller castings

Alloy type	C Max. (%)	Mn Max. (%)	Cr (%)	Mo Max. (%) (*see* Note)	Ni (%)
Martensitic (12Cr 1Ni)	0,15	2,0	11,5–17,0	0,5	Max. 2,0
Martensitic (13Cr 4Ni)	0,06	2,0	11,5–17,0	1,0	3,5–5,0
Martensitic (16Cr 5Ni)	0,06	2,0	15,0–17,5	1,5	3,5–6,0
Austenitic (19Cr 11Ni)	0,12	1,6	16,0–21,0	4,0	8,0–13,0

NOTE
Minimum values are to be in accordance with the agreed specification or recognised National or International Standards.

Table 4.5.2 Typical mechanical properties for steel propeller castings

Alloy type	Yield stress or, 0,2% proof stress minimum, N/mm^2	Tensile strength minimum N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests J minimum (*see* Notes 1 and 2)
Martensitic (12Cr 1Ni)	440	590	15	30	20
Martensitic (13Cr 4Ni)	550	750	15	35	30
Martensitic (16Cr 5Ni)	540	760	15	35	30
Austenitic (19Cr 11Ni)	180 (*see* Note 3)	440	30	40	—

NOTES
1. When a general service notation **Ice Class 1AS, 1A, 1B or 1C** is required, the tests are to be made at –10°C.
2. For general service or where the notation **Ice Class 1D** is required, the tests are to be made at 0°C.
3. $R_{p1,0}$ value is 205 N/mm^2.

5.6 Rectification of defective castings

5.6.1 The rectification of defective castings is to be undertaken in accordance with 1.9 and the following paragraphs.

5.6.2 Removal of defective material is to be by mechanical means, e.g., by grinding, chipping or milling. The resultant grooves are to be blended into the surrounding surface so as to avoid any sharp contours.

5.6.3 Grinding in severity zone A may be carried out to an extent that maintains the blade thickness. Repair by welding is generally not permitted in zone A and will only be allowed after special consideration.

5.6.4 Defects in severity zone B that are not deeper than t/40 mm (t is the minimum local thickness according to the Rules) or 2 mm, whichever is the greater, are to be removed by grinding. Those defects that are deeper may be repaired by welding subject to prior approval of the Surveyor.

5.6.5 Repair welding is generally permitted in severity zone C.

5.6.6 Welds having an area of less than 5 cm^2 are to be avoided. The maximum surface area of repairs is to be in accordance with Table 9.1.4 in Chapter 9.

5.6.7 Welding is to be in accordance with the approved specification, *see* 5.1.3.

5.6.8 After weld repair, the propeller or blade is to be heat treated in such fashion as will minimise the residual stresses. For martensitic stainless steels, this will involve full heat treatment as specified in the approved specification.

5.6.9 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

5.6.10 All welds are to be inspected by the appropriate NDE method, *see* 1.7.

5.7 Identification

5.7.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Type of steel, this should include or allow identification of the chromium and nickel contents.
(c) LR or Lloyd's Register and the abbreviated name of Lloyd's Register's local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) LR certificate number.
(f) Skew angle, if in excess of 25°.
(g) Ice class symbol, where applicable.
(h) Date of final inspection.

5.8 Certification of materials

5.8.1 In addition to the requirements in Ch 4,1.11, the manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting:

(a) Description of casting with drawing number.
(b) Diameter, number of blades, pitch, direction of turning.
(c) Skew angle, if in excess of 25°.
(d) Final mass.
(e) Vessel identification, where known.

■ *Section 6*
Castings for boilers, pressure vessels and piping systems

6.1 Scope

6.1.1 This Section gives the requirements for carbon-manganese and alloy steel castings for boilers, pressure vessels and piping systems for use at temperatures not lower than 0°C.

6.1.2 Where it is proposed to use alloy steels other than as given in this Section, details of the specification are to be submitted for approval. In such cases, the specified minimum tensile strength is not to exceed 600 N/mm^2.

6.1.3 Castings which comply with these requirements are acceptable for liquefied gas piping systems where the design temperature is not lower than 0°C. Where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required, the castings are to comply with the requirements of Section 7 or 8.

6.2 Chemical composition

6.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.6.1.

6.3 Heat treatment

6.3.1 Castings are to be supplied:

(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.

6.4 Mechanical tests

6.4.1 A tensile test is to be made on material representing each casting, unless a batch testing procedure has been agreed, *see* 1.6.

6.4.2 The tensile test is to be carried out at ambient temperature, and unless agreed otherwise with the Surveyor, the results are to comply with the requirements of Table 4.6.2.

Table 4.6.1 Chemical composition of steel castings for boilers, pressure vessels and piping systems

Type of steel	Chemical composition %										
	C max.	Si max.	Mn	S max.	P max.	Residual elements					
Carbon-manganese	0,25	0,60	0,50-1,20	0,040	0,040	Cr 0,30 max. Mo 0,15 max. Cu 0,30 max. Ni 0,40 max. Total 0,80 max.					
						Cr	Mo	V	Residual elements Cr	Cu	Ni
$\frac{1}{2}$ Mo	0,20	0,60	0,50–1,00	0,040	0,040	—	0,45-0,65	—	0,30 max.	0,30 max.	0,40 max.
1 Cr $\frac{1}{2}$ Mo	0,20	0,60	0,50-0,80	0,040	0,040	1,00-1,50	0,45-0,65	—	—	0,30 max.	0,40 max.
2 $\frac{1}{4}$ Cr1 Mo	0,18	0,60	0,40-0,70	0,040	0,040	2,00-2,75	0,90-1,20	—	—	0,30 max.	0,40 max.
$\frac{1}{2}$ Cr $\frac{1}{2}$ Mo $\frac{1}{4}$ V	0,10–0,15	0,45	0,40-0,70	0,030	0,030	0,30-0,50	0,40-0,60	0,22-0,30	—	0,30 max.	0,30 max.

Table 4.6.2 Mechanical properties for acceptance purposes: steel castings for boilers, pressure vessels and piping systems

Type of steel	Yield stress minimum N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum
Carbon-manganese	275	485-655	22	25
$\frac{1}{2}$Mo	260	460-590	18	30
1Cr$\frac{1}{2}$Mo	280	480-630	17	20
2$\frac{1}{4}$ Cr1 Mo	325	540-630	17	20
$\frac{1}{2}$Cr$\frac{1}{2}$Mo$\frac{1}{4}$V	295	510-660	17	20

6.4.3 Where it is proposed to use a carbon-manganese steel with a specified minimum tensile strength intermediate to those given in this Section, corresponding minimum values for the yield stress, elongation and reduction of area may be obtained by interpolation.

6.4.4 Carbon-manganese steels with a specified minimum tensile strength of greater than 490 N/mm^2, but not exceeding 520 N/mm^2, may be accepted provided that details of the proposed specification are submitted for approval.

6.5 Non-destructive examination

6.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally as agreed between the manufacturer, purchaser and Surveyor.

6.6 Mechanical properties for design purposes

6.6.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 100°C and higher are given in Table 4.6.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 4.6.3.

6.6.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each casting or each batch of castings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

6.6.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 4.6.4 and may be used for design purposes.

Table 4.6.3 Mechanical properties for design purposes (*see* 6.6.1)

Type of steel	Nominal minimum lower yield or 0,2% proof stress N/mm^2										
	Temperature °C										
	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese	225	214	201	186	163	156	152	—	—	—	—
$^1/_2$Mo	242	236	226	207	186	175	169	158	145	136	126
1Cr$^1/_2$Mo	240	—	212	—	196	—	184	—	160	—	117
2$^1/_4$Cr1 Mo	323	312	305	296	290	280	273	258	240	211	180
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	264	—	244	—	230	—	214	—	194	—	144

Table 4.6.4 Mechanical properties for design purposes (*see* 6.6.3)**: estimated average stresses to rupture in 100,000 hours (N/mm^2)**

Temperature °C	Type of steel			
	$^1/_2$Mo	1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo	$^1/_2$Cr$^1/_2$Mo$^1/_4$V
430	308	—	—	—
440	276	—	—	—
450	245	—	222	277
460	212	—	199	237
470	174	236	177	206
480	133	186	156	181
490	103	148	139	159
500	84	120	124	140
510	71	100	111	124
520	60	84	99	109
530	—	70	—	96
540	—	58	—	85
550	—	—	—	75
560	—	—	—	66

■ *Section 7*
Ferritic steel castings for low temperature service

7.1 Scope

7.1.1 This Section gives the requirements for castings in carbon-manganese and nickel alloy steels, intended for use in liquefied gas piping systems where the design temperature is lower than 0°C, and for other applications where guaranteed impact properties at low temperatures are required.

7.1.2 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the limits specified in Table 4.7.1. Carbon-manganese steels are to be made by fine grain practice.

7.3 Heat treatment

7.3.1 Castings are to be supplied:
(a) normalised; or
(b) normalised and tempered; or
(c) quenched and tempered.

7.4 Mechanical tests

7.4.1 One tensile test and one set of three Charpy V-notch impact test specimens are to be prepared from material representing each casting or batch of castings.

7.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the appropriate requirements given in Table 4.7.2.

7.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.7.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedure.

7.5 Non-destructive examination

7.5.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

Table 4.7.1 Chemical composition of ferritic steel castings for low temperature service

Type of steel	Chemical composition %						
	C max.	Si max.	Mn	S max.	P max.	Ni	Residual elements max.
Carbon-manganese	0,25	0,60	0,70-1,60	0,030	0,030	0,80 max.	Cr 0,25 Cu 0,30 Mo 0,15 V 0,03 Total 0,60
$2^1/_4$Ni	0,25	0,60	0,50-0,80	0,025	0,030	2,00-3,00	
$3^1/_2$Ni	0,15	0,60	0,50-0,80	0,020	0,025	3,00-4,00	

Table 4.7.2 Mechanical properties for acceptance purposes: ferritic steel castings for low temperature service

Type of steel	Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Reduction or area % minimum	Charpy V-notch impact test	
						Test temperature °C	Average energy J minimum
Carbon-manganese	400 430 460	200 215 230	400-550 430-580 460-610	25 23 22	40 35 30	–60 (*see* Note)	27
$2^1/_4$Ni	490	275	490-640	20	35	–70	34
$3^1/_2$Ni	490	275	490-640	20	35	–95	34

NOTE
The test temperature for carbon-manganese steels may be 5°C below the design temperature if the latter is above –55°C, with a maximum test temperature of –20°C.

■ *Section 8* Stainless steel castings

8.1 Scope

8.1.1 This Section gives the requirements for castings in austenitic and duplex stainless steels for machinery, marine structures, piping systems in ships for liquefied gases, and in bulk chemical tankers.

8.1.2 Austenitic stainless steels castings are suitable for applications where the lowest design temperature is not lower than –165°C.

8.1.3 Duplex stainless steels castings are suitable for applications where the lowest design temperature is above 0°C. Any requirement to use duplex stainless steels castings below 0°C will be subject to special consideration.

8.1.4 Where it is proposed to use alternative steels, particulars of the specified chemical composition, mechanical properties and heat treatment are to be submitted for approval.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is to comply with the requirements given in Table 4.8.1.

8.3 Heat treatment

8.3.1 Austenitic stainless steel castings are to be solution treated, at a temperature of not less than 1000°C and cooled rapidly in water.

8.3.2 Duplex stainless steels castings are to be solution treated at a temperature of not less that 1100°C and cooled rapidly in water.

8.4 Mechanical tests

8.4.1 One tensile test specimen is to be prepared from material representing each casting or batch of castings. In addition, where the castings are intended for liquefied gas applications, where the design temperature is lower than –55°C, one set of three Charpy V-notch impact test specimens is to be prepared.

8.4.2 The tensile test is to be carried out at ambient temperature, and the results are to comply with the requirements given in Table 4.8.2.

Table 4.8.1 Chemical composition of stainless steel castings

<table>
<tr><th rowspan="2">Type of steel</th><th colspan="9">Chemical composition %</th></tr>
<tr><th>C</th><th>Si</th><th>Mn</th><th>S</th><th>P</th><th>Cr</th><th>Mo</th><th>Ni</th><th>Others</th></tr>
<tr><td colspan="10">Austenitic</td></tr>
<tr><td>304L</td><td>0,03</td><td rowspan="6">0,20-1,5</td><td rowspan="6">0,50-2,0</td><td rowspan="6" colspan="2">0,040</td><td rowspan="6">17,0-21,0</td><td>—</td><td>8,0–12,0</td><td>—</td></tr>
<tr><td>304</td><td>0,08</td><td>—</td><td>8,0–12,0</td><td>—</td></tr>
<tr><td>316L</td><td>0,03</td><td>2,0–3,0</td><td>9,0–13,0</td><td>—</td></tr>
<tr><td>316</td><td>0,08</td><td>2,0–3,0</td><td>9,0–13,0</td><td>—</td></tr>
<tr><td>317</td><td>0,08</td><td>3,0–4,0</td><td>9,0–12,0</td><td>—</td></tr>
<tr><td>347
(*see* Note 1)</td><td>0,06</td><td>—</td><td>9,0–12,0</td><td>Nb
≥ 8 x C
≤ 0,90</td></tr>
<tr><td colspan="10">Duplex</td></tr>
<tr><td>UNS S 31803</td><td>0,03</td><td>1,00</td><td>2,00</td><td>0,025</td><td>0,035</td><td>21,0–23,0</td><td>2,5–3,5</td><td>4,5–6,5</td><td>N
0,08–0,20</td></tr>
<tr><td colspan="10">NOTES
1. When guaranteed impact values at low temperature are not required, the maximum carbon content may be 0,08% and the maximum niobium may be 1,00%.
2. Where a single value is shown (and not a range of values), the value is to be taken as maximum.</td></tr>
</table>

Table 4.8.2 Mechanical properties for acceptance purposes: stainless steel castings

<table>
<tr><th rowspan="2">Type of steel</th><th rowspan="2">Tensile strength N/mm^2 minimum</th><th rowspan="2">1,0% proof stress N/mm^2 minimum</th><th rowspan="2">Elongation on 5,65 $\sqrt{S_o}$ % minimum</th><th rowspan="2">Reduction of area % minimum</th><th colspan="2">Charpy V-notch impact tests</th></tr>
<tr><th>Test temperature °C</th><th>Average energy J minimum</th></tr>
<tr><td colspan="7">Austenitic</td></tr>
<tr><td>304L</td><td>430</td><td>215</td><td rowspan="2">26</td><td rowspan="2">40</td><td rowspan="2">–196</td><td rowspan="2">41</td></tr>
<tr><td>304</td><td>480</td><td>220</td></tr>
<tr><td>316L</td><td>430</td><td>215</td><td rowspan="3">26</td><td rowspan="3">40</td><td rowspan="3">–196</td><td rowspan="3">41</td></tr>
<tr><td>316</td><td>480</td><td>220</td></tr>
<tr><td>317</td><td>480</td><td>240</td></tr>
<tr><td>347</td><td>480</td><td>215</td><td>22</td><td>35</td><td>–196</td><td>41</td></tr>
<tr><td colspan="7">Duplex</td></tr>
<tr><td>UNS S 31803</td><td>600</td><td>420</td><td>20</td><td>35</td><td>0</td><td>41</td></tr>
</table>

8.4.3 The average value for impact test specimens is to comply with the appropriate requirements given in Table 4.8.2. One individual value may be less than the required average value, provided that it is not less than 70 per cent of this average value. *See* Ch 2,1.4 for re-test procedures.

8.5 Intergranular corrosion tests

8.5.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on castings in grades 304, 316, 317 and all duplex stainless steels. Such tests may not be required for grades 304L, 316L and 347.

8.5.2 Where an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

8.6 Non-destructive examination

8.6.1 The non-destructive examination of castings is to be carried out in accordance with the appropriate requirements of 1.7.7 to 1.7.11 and additionally agreed between the manufacturer, purchaser and Surveyor.

Section 9 Steel castings for container corner fittings

9.1 General

9.1.1 This Section gives the requirements for cast steel corner fittings used in the fabrication of freight and tank containers. The fittings are also to comply with the requirements of the latest edition of International Standard ISO 1161.

9.1.2 The castings are to be made in foundries approved by LR. These foundries are also to be specially approved for the manufacture of container corner castings. In order to comply with these requirements, the manufacturer is required to verify that the casting soundness, mechanical properties, weldability and dimensional tolerances required by this Section and the manufacturing specification are met.

9.1.3 Castings may be released on the basis of an LR survey or, alternatively, the manufacturer may be approved by means of a Quality Assurance Scheme as detailed in Ch 1,2.

9.2 Chemical composition

9.2.1 Chemical analysis is to be carried out on each cast.

9.2.2 The chemical composition of the ladle samples is to comply with the limits given in Table 4.9.1.

9.2.3 The carbon equivalent:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \ (\%)$$

must not exceed 0,45 per cent.

9.3 Heat treatment

9.3.1 Castings are to be supplied either:

(a) normalised; or

(b) water or oil quenched and tempered at a temperature of not less than 550°C.

9.4 Mechanical tests

9.4.1 At least one tensile test is to be made on each batch of castings, using separately cast test bars which are to be from the same cast and heat treatment lot as the castings they represent.

9.4.2 The results of the tensile tests are to comply with the following:

Yield stress	220 N/mm^2 min.
Tensile strength	430–600 N/mm^2
Elongation on $\sqrt{S_o}$	25% min.
Reduction of area	40% min.

9.4.3 Impact tests are not required on all casts, but may be required on a random basis at the discretion of the Surveyor.

9.4.4 When required, the impact test specimens are to be tested in accordance with Ch 1,4.5 and Ch 2,3.2. In general, tests are to be made at a temperature of –20°C and the minimum average energy obtained is to be 27J.

9.5 Non-destructive examination

9.5.1 Ultrasonic or radiographic testing is to be carried out, in accordance with 1.7.10 or 1.7.11 respectively, on at least one casting from each cast or from every 400 castings, whichever is the lesser.

9.6 Repair of defects

9.6.1 Minor defects may be removed by grinding provided that the allowable minus tolerance is not exceeded.

Table 4.9.1 Chemical composition of steel castings for container corner fittings

Chemical composition %										
C max.	Mn	Si max.	P max.	S max.	Cr max.	Ni max.	Cu max.	Mo max.	Al acid soluble min. (*See* Notes)	Cr + Ni + Cu + Mo max.
0,20	0,90 to 1,50	0,50	0,035	0,035	0,25	0,30	0,20	0,08	0,015	0,70

NOTES
1. The total aluminium content may be determined instead of the acid soluble content. In such cases, the total aluminium content is to be not less than 0,02%.
2. Aluminium may be replaced partly or totally by other grain refining elements as stated in the approved specification.

9.6.2 Defects which exceed the allowable minus tolerance may be removed by grinding or chipping followed by welding, provided the weld depth does not exceed 40 per cent of the wall thickness and that the following requirements are met:

(a) welding is not to be carried out in the as-cast condition; the grain structure has to be refined by heat treatment,
(b) the casting is to be preheated to 80–100°C,
(c) welding is to be performed only by qualified welders in accordance with a qualified welding procedure,
(d) all welded castings are to be post-weld heat treated at a temperature not less than 550°C,
(e) the welded areas are to be ground or machined flush with the adjacent surface and inspected by magnetic particle or dye penetrant examination as appropriate.

9.7 Identification

9.7.1 Each casting is to be clearly marked by the manufacturer with at least the following:

(a) manufacturer's name or trade mark,
(b) cast number or identification number which will enable the full history of the casting to be traced.

9.7.2 Where the casting has been inspected and found acceptable it is to be marked with the Surveyor's personal stamp.

9.7.3 The markings may be stamped or cast on the inner surface of the casting.

9.8 Certification of materials

9.8.1 For each consignment a manufacturer's certificate is to be issued (*see* Ch 1,3.1), containing at least the following:

(a) Purchaser's name and order number.
(b) Grade of steel.
(c) Drawing and/or specification number.
(d) Cast number and chemical composition.
(e) Details of the heat treatment.
(f) Number and weight of the castings.
(g) Results of inspections and mechanical tests.

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for steel forgings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems. These requirements are also applicable to rolled slabs and billets used as a substitute for forgings and to rolled bars used for the manufacture (by machining operations only) of shafts, bolts, studs and other components of similar shape.

1.1.2 When required by the relevant Rules dealing with design and construction, forgings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the general requirements given in this Section and the appropriate specific requirements given in Sections 2 to 9.

1.1.3 As an alternative to 1.1.2, steel forgings which comply with National or proprietary specifications, may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter, or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Normalised forgings with mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch is to consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 tonnes for normalised forgings and 3 tonnes for quenched and tempered forgings, respectively.

1.1.5 A batch testing procedure may also be used for hot rolled bars, *see* 3.4.3.

1.1.6 Where small forgings are produced in large quantities, or where forgings of the same type are produced in regular quantities, alternative survey procedures in accordance with Ch 1,2.4 may be adopted.

1.2 Manufacture

1.2.1 Forgings are to be made at works which have been approved by Lloyd's Register (hereinafter referred to as LR). The steel used, is to be manufactured in accordance with the requirements of Ch 3,1.3.

1.2.2 When forgings are made directly from ingots, or from blooms or billets forged from ingots, the ingots are to be cast in chill moulds with the larger cross-section uppermost and with efficient feeder heads.

1.2.3 Adequate top and bottom discards are to be made to ensure freedom from piping and harmful segregations in the finished forgings.

1.2.4 The forgings are to be gradually and uniformly hot worked and are to be formed as closely as possible to the finished shape and size. The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment.

1.2.5 For certain components, such as crankshafts, where grain flow is required in the most favourable direction, having regard to the mode of stressing in service, the proposed method of manufacture may require special approval by LR. In such cases, tests may be required to demonstrate that a satisfactory structure and grain flow are obtained.

1.2.6 The reduction ratio (reduction of area expressed as a ratio) is to be calculated with reference to the average cross-sectional area of the ingot or continuously cast material, where appropriate. Where an ingot is initially upset, this reference area may be taken as the average cross-sectional area after this operation.

1.2.7 For components forged directly from ingots or from forged blooms or billets, and in which the fibre deformation is mainly longitudinal, the reduction ratio is not to be less than 3:1.

1.2.8 For forgings made from rolled billets, or where fibre deformation has taken place in more than one direction, the reduction ratio is not to be less than 4:1.

1.2.9 Where rolled bars are used as a substitute for forgings and the requirements of 1.2.2 are not complied with, the reduction ratio is to be not less than 6:1.

1.2.10 Where the length of any section of a shaft forging is less than its diameter (e.g., a collar), the reduction ratio is to be not less than half that given in 1.2.7, 1.2.8 or 1.2.9 respectively.

1.2.11 Disc type forgings, such as gear wheels, are to be made by upsetting, and the thickness of any part of the disc is to be not more than one-half of the length of the billet from which it was formed, provided that this billet has received an initial forging reduction of not less than 1,5:1. Where the piece used has been cut directly from an ingot, or where the billet has received an initial reduction of less than 1,5:1, the thickness of any part of the disc is to be not more than one-third of the length of the original piece.

1.2.12 Rings and other types of hollow forgings are to be made from pieces cut from ingots or billets and which have been suitably punched, bored or trepanned prior to expanding or hollow forging. Alternatively, pieces from hollow cast ingots may be used. The wall thickness of the forging is to be not more than one-half of the thickness of the prepared hollow piece from which it was formed. Where this is not practicable, the forging procedure is to be such as to ensure that adequate work is given to the piece prior to punching, etc. This may be either longitudinal or upset working of not less than 2:1.

1.2.13 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging is to be undertaken in accordance with recognised good practice and, unless otherwise approved, is to be carried out before the final heat treatment. Preheating is to be employed where necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required, *see* 4.2.4.

1.2.14 Where two or more forgings are joined by welding to form a composite component, details of the proposed welding procedure are to be submitted for approval. Welding approval procedure tests may be required.

1.3 Quality

1.3.1 All forgings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.4 Chemical composition

1.4.1 All forgings are to be made from killed steels, and the chemical composition of ladle samples is to comply with the requirements detailed in subsequent Sections in this Chapter. Where general overall limits are specified, the chemical composition selected is to be appropriate for the type of steel, dimensions and required mechanical properties of the forgings being manufactured.

1.4.2 Except where otherwise specified, suitable grain refining elements such as aluminium, niobium or vanadium may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

1.4.3 For alloy steel forgings, the chemical composition of ladle samples is to generally comply with the following overall limits and the requirements of the approved specifications:

Carbon	0,45% max.
Silicon	0,45% max.
Manganese	0,30% min.
Sulphur	0,035% max.
Phosphorus	0,035% max.
Copper	0,30% max.

And at least one of the following elements is to comply with the minimum content:

Chromium	0,40% min.
Molybdenum	0,15% min.
Nickel	0,40% min.

The contents of all alloying elements and significant impurities detailed in the specification are to be reported.

1.5 Heat treatment

1.5.1 At an appropriate stage of manufacture, after completion of all hot working operations, forgings are to be suitably heat treated to refine the grain structure and to obtain the required mechanical properties. Acceptable heat treatment procedures are to be such as to avoid the formation of hair-line cracks and are detailed in Sections 2 to 9.

1.5.2 Heat treatment is to be carried out in properly constructed furnaces, which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions are to be such as to allow the whole furnace charge to be uniformly heated to the necessary temperature. In the case of very large forgings, alternative methods of heat treatment will be specially considered. Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform. Alternative procedures are to be approved by LR, Materials and NDE Department.

1.5.3 Where forgings are to be quenched and tempered and cannot be hot worked close to size and shape, they are to be suitably rough machined or flame cut prior to being subjected to this treatment.

1.5.4 If for any reason a forging is subsequently heated for further hot working, the forging is to be reheat treated.

1.5.5 If any straightening operation is performed after the final heat treatment, consideration should be given to a subsequent stress relieving heat treatment in order to avoid the possibility of harmful residual stresses.

1.5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for approval. For the purposes of this approval, the manufacturer will be required to demonstrate by tests that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel.

1.5.7 Where induction hardening or nitriding is to be carried out after machining, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

1.5.8 Where carburising is to be carried out after machining, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalising and tempering) to a condition suitable for subsequent machining and carburising.

1.5.9 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, thermocouple location, date, temperature and time at temperature. The records are to be presented to the Surveyor on request.

1.6 Test material

1.6.1 Test material, sufficient for the required tests and for possible re-test purposes, is to be provided with a cross-sectional area of not less than that part of the forging which it represents. This test material is to be integral with each forging, except in the case of small forgings which are batch tested, *see* 1.6.4.

1.6.2 Where a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required is to be related to the total length and mass of the original multiple forging, *see* 2.4.2.

1.6.3 Except for components which are to be carburised, test material is not to be cut from a forging until the heat treatment detailed in Sections 2 to 9 has been completed. The testing procedure for components which are to be carburised is to be in accordance with the details given in Section 5.

1.6.4 Where a number of small forgings of about the same size are made from one cast and heat treated in the same furnace charge, batch testing procedures (*see* 1.1.4) may be adopted using one of the forgings for test purposes, or alternatively using separately forged test samples. These test samples are to have a forging reduction similar to that used for the forgings which they represent. They are to be properly identified and heat treated together with the forgings.

1.7 Mechanical tests

1.7.1 Specimens for mechanical tests are to be prepared as required by Sections 2 to 9.

1.7.2 Test specimens are normally to be cut with their axes mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

1.7.3 Unless otherwise agreed, the longitudinal axis of the test specimens is to be positioned as follows:

(a) for thickness or diameter $\leq$ 50 mm, the axis is to be at the mid-thickness or the centre of the cross-section;

(b) for thickness or diameter > 50 mm, the axis is to be at one quarter thickness (mid-radius) or 80 mm, whichever is less, below any heat treated surface;

Test pieces shall be taken in such a way that no part of the gauge length is machined from material closer than 12,5 mm to any heat treated surface. For impact testing, this requirement is to apply to the complete test piece.

1.7.4 Tensile test specimens are to be machined to the dimensions detailed in Chapter 2. Where this is precluded by the dimensions of the forging, the test specimen is to be of the largest practicable cross-sectional area.

1.7.5 Impact test specimens are to be prepared in accordance with the requirements of Chapter 2.

1.7.6 The procedures used for the tensile and impact tests are to be in accordance with the requirements of Chapter 2.

1.7.7 Hardness tests, preferably of the Brinell type, are to be carried out when specified in subsequent Sections in this Chapter.

1.8 Visual and non-destructive examination

1.8.1 Before acceptance, all forgings are to be presented to the Surveyor for visual examination. Where applicable, this is to include the examination of internal surfaces and bores.

1.8.2 Forgings are to be examined in the condition for final delivery. Surfaces are to be clean and free from dirt, grease, paint, etc. Black forgings are to be suitably descaled by either shotblasting or flame descaling methods.

1.8.3 All forgings are to be free of cracks, crack-like indications, laps, seams, folds, or other injurious indications. At the request of the Surveyor, additional magnetic particle, dye penetrant and ultrasonic testing may be required for a more detailed evaluation of surface irregularities.

1.8.4 When specified in subsequent Sections in this Chapter, or by an approved procedure for welding composite components, *see* 1.2.14, appropriate non-destructive examination is also to be carried out before acceptance. All tests are to be carried out in accordance with the requirements of Ch 1,5.

1.8.5 Magnetic particle and dye penetrant testing is to be carried out when the forgings are in the finished machined condition, *see also* Ch 1,2.3.5. For magnetic particle testing, attention is to be paid to the contact between the forging and the clamping devices of stationary magnetisation benches in order to avoid local overheating or burning damage on its surface. Prods are not permitted on finished machined items. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyor.

1.8.6 The following definitions apply to indications associated with magnetic particle and dye penetrant inspection:

(a) **Linear indication**. An indication in which the length is at least three times the width.
(b) **Nonlinear indication**. An indication of circular or elliptical shape with a length less than three times the width.
(c) **Aligned indication**. Three or more indications in a line, separated by 2 mm or less edge-to-edge.
(d) **Open indication**. An indication visible after removal of the magnetic particles or that can be detected by the use of contrast dye penetrant.
(e) **Non-open indication**. An indication that is not visually detectable after removal of the magnetic particles or that cannot be detected by the use of contrast dye penetrant.
(f) **Relevant indication**. An indication that is caused by a condition or type of discontinuity that requires evaluation. Only indications which have any dimension greater than 1,5 mm are to be considered relevant.

1.8.7 Acceptance standards for defects found by visual or non destructive examinations are to be in accordance with any specific requirements of the approved plan, and with equivalence to any additional requirements of this Chapter. In all cases they are to be to the satisfaction of the Surveyor.

1.8.8 Where required, ultrasonic examination is to be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning are to be carried out where appropriate for the shape and the dimensions of the forgings being examined. Unless otherwise agreed, this examination is to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

1.8.9 If the forging is supplied in the black condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

1.8.10 In the circumstance detailed in either 1.8.8 or 1.8.9, the manufacturer is to provide the Surveyor with a signed report confirming that ultrasonic examination has been carried out and that such inspection has not revealed any significant internal defects.

1.8.11 Unless otherwise agreed, the accuracy and verification of dimensions are the responsibility of the manufacturer.

1.8.12 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

1.8.13 When required by the conditions of approval for surface hardened forgings (*see* 1.5.6) additional test samples are to be processed at the same time as the forgings which they represent. These test samples are subsequently to be sectioned in order to determine the hardness, shape and depth of the locally hardened zone and which are to comply with the requirements of the approved specification.

1.9 Rectification of defects

1.9.1 Small surface imperfections may be removed by grinding or by chipping and grinding. Complete elimination of these imperfections is to be proved by magnetic particle or dye penetrant examination (as appropriate to the material). At the discretion of the Surveyor, the resulting shallow grooves or depressions can be accepted, provided that they are blended by grinding.

1.9.2 Repairs by welding are not generally permitted, but special consideration will be given to such repairs where they are of a minor nature and in areas of low working stresses. In such cases, full details of the proposed repair and subsequent inspection procedures are to be submitted for review by the Surveyors prior to the commencement of the proposed rectification. A report and/or sketch detailing the extent and location of all repairs, together with details of the post-weld heat treatment and non-destructive examination are to be provided for record purposes and are to be attached to the certificate.

1.9.3 Repair welding is not permitted for crankshafts or similar rotating components.

1.9.4 Where fabrication welding is involved, *see* 1.2.14, any repair of defects is to be carried out in accordance with the approved welding procedure.

1.9.5 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging. The records are to be presented to the Surveyor on request.

1.9.6 Non-open indications evaluated as segregation are acceptable.

1.10 Identification

1.10.1 The manufacturer is to adopt a system of identification, which will enable all finished forgings to be traced to the original cast, forging process and heat treatment batch, and the Surveyor is to be given full facilities for so tracing the castings when required.

1.10.2 Forgings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all forgings which have been accepted:

(a) Identification number, cast number or other marking which will enable the full history of the forging to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

1.10.3 Modified arrangements for the identification of small forgings manufactured in large numbers, as with closed-die forgings may be agreed with the Surveyor.

1.11 Certification of materials

1.11.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.11.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each forging or batch of forgings which has been accepted:
(a) Purchaser's name and order number.
(b) Description of forgings and steel quality.
(c) Identification number.
(d) Steelmaking process, cast number and chemical analysis of ladle samples.
(e) General details of heat treatment.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

1.11.3 As a minimum, the chemical composition of ladle samples is to include the content of all the elements detailed in the specific requirements.

1.11.4 Where applicable, the manufacturer is also to provide a signed report regarding ultrasonic examination as required by 1.8.8, a report of magnetic particle inspection and a statement and/or sketch detailing all repairs by welding as required by 1.9.2.

1.11.5 When steel is not produced at the works at which it is forged, a certificate is to be supplied by the steelmaker stating the process of manufacture, cast number and the chemical composition of ladle samples. The works at which the steel was produced is to have been approved by LR, *see* 1.4.3.

■ *Section 2* Forgings for ship and other structural applications

2.1 Scope

2.1.1 This Section gives the specific requirements for carbon-manganese steel forgings intended for ship and other structural applications such as rudder stocks, pintles, etc.

2.1.2 Where it is proposed to use an alloy steel, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval, *see* 1.4.3.

2.2 Chemical composition

2.2.1 For forgings to which structural items are to be attached by welding or which are intended for parts of a fabricated component, or are to be weld cladded or may be subject to weld repair in service, the chemical composition of ladle samples is to comply with the following:

Carbon	0,23% max.
Silicon	0,45% max.
Manganese	0,30–1,50% but not less than 3 times the actual carbon content for components which are not given a post-weld heat treatment
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

For samples from forgings, the carbon content is not to exceed 0,26 per cent.

2.2.2 It is recommended that forgings for rudder stocks, pintles and rudder coupling bolts comply with 2.2.1 in order to obtain satisfactory weldability for any future repairs by welding in service.

2.2.3 For forgings not intended for welding the carbon content may be 0,65 per cent max., *see* 3.2.1.

2.3 Heat treatment

2.3.1 Carbon-manganese steel forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered at a temperature of not less than 550°C.
(d) quenched and tempered.

2.3.2 Alloy steel forgings are to be quenched and then tempered at a temperature of not less than 550°C. Alternatively, they may be supplied in the normalised and tempered condition, in which case the specified mechanical properties are to be agreed by LR.

2.4 Mechanical tests

2.4.1 At least one tensile specimen is to be taken from each forging or batch of forgings.

2.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, tensile test specimens are to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

2.4.3 Unless otherwise agreed between the manufacturer and the Surveyor, the test specimens are to be cut in a longitudinal direction.

2.4.4 The results of all tensile tests are to comply with the requirements given in Table 5.2.1 appropriate to the specified minimum tensile strength. Forgings may be supplied to any specified minimum tensile strength within the general limits given in Table 5.2.1, and intermediate values may be obtained by interpolation. *See* 2.4.6 for rudder stocks, pintles, and rudder coupling keys and bolts.

2.4.5 For large forgings, where tensile tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

Table 5.2.1 Mechanical properties for ship and other structural applications

Steel type	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
			Long.	Tang.	Long.	Tang.
C and C-Mn	180	360-480	28	20	50	35
	200	400-520	26	19	50	35
	220	440-560	24	18	50	35
	235	470-590	23	17	45	35
	240	480-600	22	16	45	30
	260	520-640	21	15	45	30
	280	560-680	20	14	40	27
	300	600-750	18	13	40	27
	320	640-790	17	12	40	27
	340	680-830	16	12	35	24
	360	720-870	15	11	35	24
	380	760-910	14	10	35	24
Alloy	350	550-570	20	14	50	35
	400	600-750	18	13	50	35
	450	650-800	17	12	50	35

2.4.6 For rudder stocks, pintles, and rudder coupling keys and bolts, the minimum specified yield strength is not to be less than 200 N/mm^2, *see* Table 13.2.4 in Pt 3, Ch 13.

2.4.7 Impact tests are required for rudder stocks to be fitted to vessels which have an ice class notation. The tests are to be carried out at minus 10°C and the average energy value is to be not less than 27J.

2.5 Non-destructive examination

2.5.1 Surface inspections are to be carried out by visual examination and magnetic particle testing (or dye penetrant testing where appropriate).

2.5.2 Surface inspections are to be carried out in the zones I and II as indicated in Fig. 5.2.1.

2.5.3 For the purpose of evaluating indications, the surface is to be divided into reference areas of 225 cm^2. The area is to be taken in the most unfavourable location relative to the indication being evaluated.

2.5.4 The allowable number and size of indications in the reference area is given in Table 5.2.2.

2.5.5 Volumetric inspection is to be carried out by ultrasonic testing using the contact method.

2.5.6 Ultrasonic testing is to be carried out on rudder stocks having a finished diameter of 200 mm or greater.

2.5.7 Ultrasonic testing is to be carried out in the zones I to III as indicated in Fig. 5.2.2. Areas may be upgraded to a higher zone at the discretion of the Surveyors.

Table 5.2.2 Steel forgings surface inspection

Inspection zone	Maximum number of indications	Type of indication	Maximum number each type	Maximum dimension, mm
I	3	Linear Non-linear Aligned	0, *see* Note 3 0, *see* Note	— 3,0 —
II	10	Linear Non-linear Aligned	3, *see* Note 7 3, *see* Note	3,0 5,0 3,0

NOTE
Linear or aligned indications are not permitted on bolts, which receive a direct fluctuating load, e.g., main bearing bolts, connecting rod bolts, crosshead bearing bolts and cylinder cover bolts.

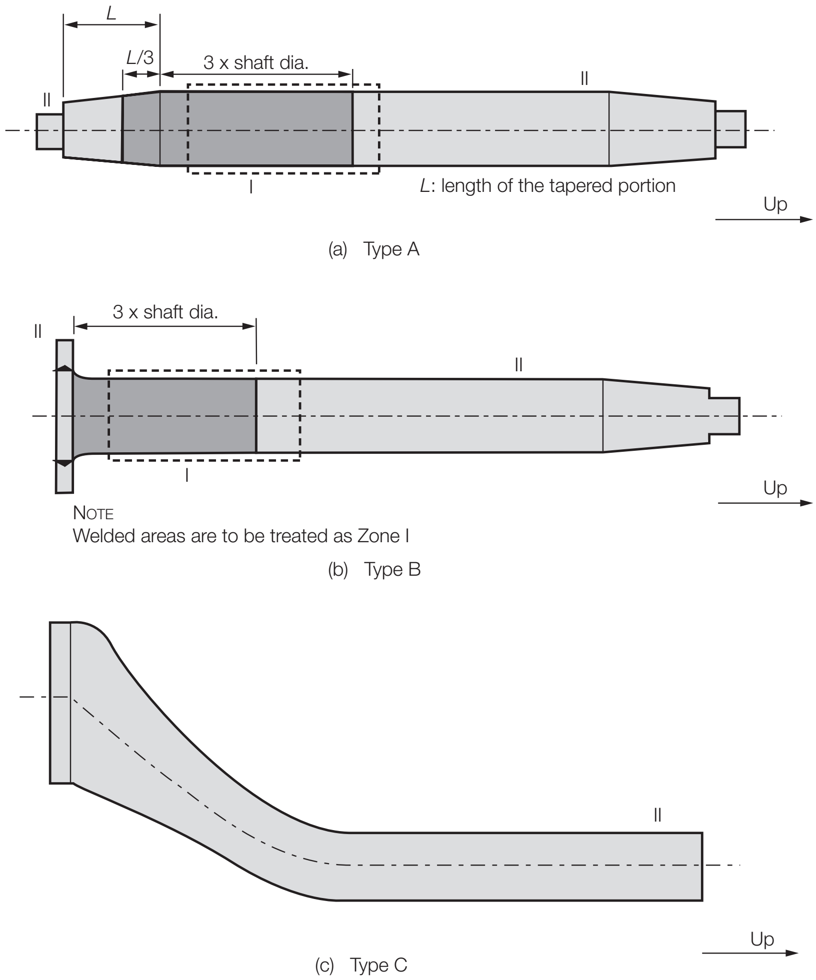


Fig. 5.2.1 Inspection zones for magnetic particle/dye penetrant testing on rudder stocks

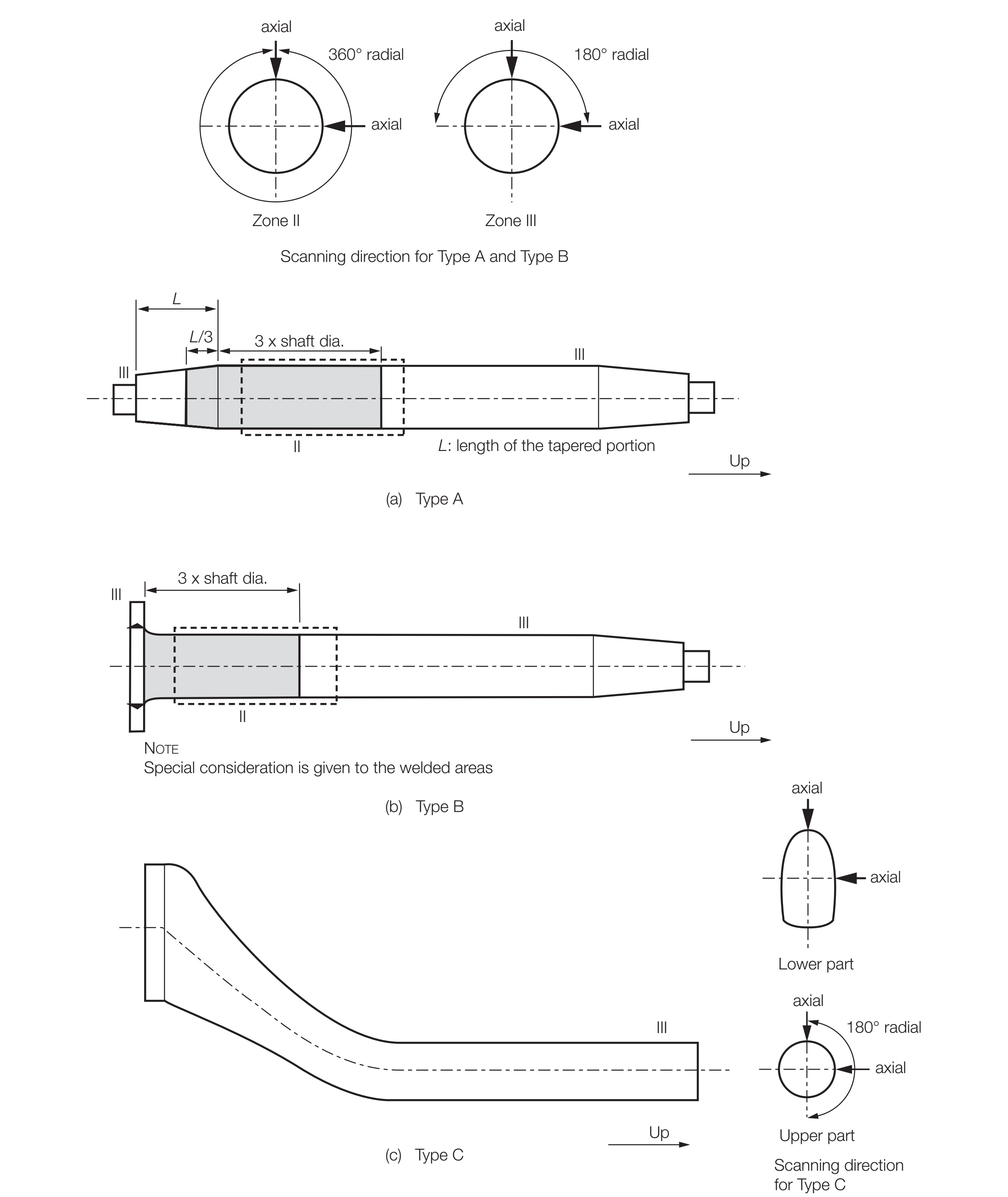


Fig. 5.2.2 Inspection zones for ultrasonic testing on rudder stocks

■ *Section 3* Forgings for shafting and machinery

3.1 Scope

3.1.1 Detailed in this Section are the requirements for carbon-manganese steel forgings for shafting and other items of machinery which are not within the scope of Sections 4 to 8.

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) and for other forgings is not to exceed 1100 N/mm^2 (1100–1300 N/mm^2 acceptance range).

3.2 Chemical composition

3.2.1 The chemical composition of ladle samples for carbon and carbon-manganese steels is to comply with the following overall limits:

Carbon	0,65% max.
Silicon	0,45% max.
Manganese	0,30–1,50%
Sulphur	0,035% max.
Phosphorus	0,035% max.
Residual elements:	
Copper	0,30% max.
Chromium	0,30% max.
Molybdenum	0,15% max.
Nickel	0,40% max.
Total	0,85% max.

3.2.2 For alloy steels, *see* 1.4.3.

3.2.3 For forgings to which structural items are to be attached by welding, or which are intended for parts of a fabricated component, are to be of weldable quality, *see* 2.2.1.

3.3 Heat treatment

3.3.1 Forgings are to be:
(a) fully annealed; or
(b) normalised; or
(c) normalised and tempered; or
(d) quenched and tempered.
The tempering temperature is to be not less than 550°C.

3.4 Mechanical tests

3.4.1 At least one tensile test is to be made on each forging, or each batch of forgings. Impact tests are not required except on screwshafts for ice service, *see* 3.4.12.

3.4.2 Where a forging exceeds both 4 tonnes in mass and 3 m in length, a tensile test is to be taken from each end. These limits refer to the 'as forged' mass and length but exclude the test material.

3.4.3 A batch testing procedure may be used for hot rolled bars not exceeding 250 mm diameter, which are intended for the manufacture (by machining operations only) of straight shafting, bolts, studs and other machinery components of similar shape. A batch is to consist of either:
(a) material from the same piece provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge; or
(b) bars of the same diameter and cast, heat treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes.

3.4.4 The test specimens are to be taken in the longitudinal direction but, at the discretion of the manufacturer and if agreed by the Surveyor, alternative directions or positions as shown in Figs. 5.3.1 to 5.3.3 may be used.

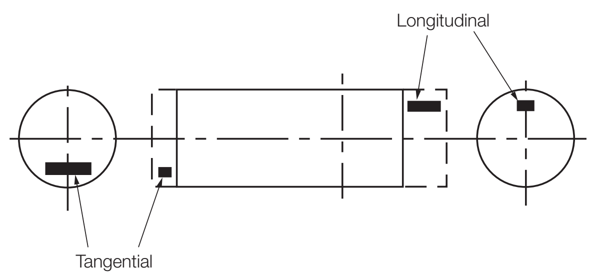


Fig. 5.3.1
Directions and positions of test specimens

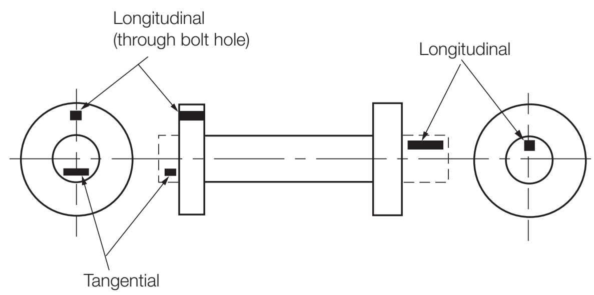


Fig. 5.3.2
Directions and positions of test specimens

3.4.5 For carbon-manganese steels, Table 5.3.1 gives the minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. Intermediate values for other specified minimum tensile strengths should be calculated by interpolation.

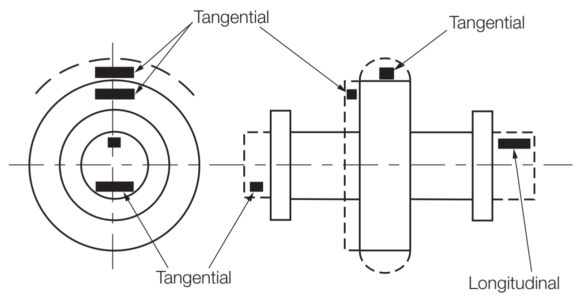


Fig. 5.3.3
Directions and positions of test specimens

3.4.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.1, except that for main propulsion shafting forgings the specified minimum tensile strength is to be not less than 400 N/mm^2 (400–520 N/mm^2 acceptance range) and not greater than 600 N/mm^2 (600–750 N/mm^2 acceptance range) *see* shaded area of Table 5.3.1.

3.4.7 The results of all tensile tests are to comply with the requirements given in Table 5.3.1 appropriate to the specified minimum tensile strength.

3.4.8 The minimum requirements for yield stress, elongation and reduction of area, corresponding to different strength levels in alloy steel forgings are given in Table 5.3.2.

Table 5.3.1 Mechanical properties for acceptance purposes: carbon and carbon-manganese steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
360-480	180	28	20	50	35
400-520	200	26	19	50	35
440-560	220	24	18	50	35
470-590	235	23	17	45	35
480-600	240	22	16	45	30
520-640	260	21	15	45	30
560-680	280	20	14	40	27
600-750	300	18	13	40	27
640-790	320	17	12	40	27
680-830	340	16	12	35	24
700-850 [2]	350	15	11	35	24
720-870 [2]	360	15	11	35	24
760-910 [2]	380	14	10	35	24

NOTES
1. For main propulsion shafting forgings, the specified minimum tensile strength is to be between 400 and 600 N/mm^2 (shaded area of Table) *see* 3.4.6.
2. Where the specified minimum tensile strength exceeds 700 N/mm^2, forgings are to be supplied only in the quenched and tempered condition.

Table 5.3.2 Mechanical properties for acceptance purposes: alloy steel forgings for machinery and shafting

Tensile strength N/mm^2	Yield stress N/mm^2	Elongation on $5,65\sqrt{S_o}$ min.%		Reduction of area min. %	
		Long.	Tang.	Long.	Tang.
600-750	420	18	14	50	35
650-800	450	17	13	50	35
700-850	480	16	12	45	30
750-900	530	15	11	45	30
800 -950	580	14	10	40	27
850-1000	630	13	9	40	27
900-1100	690	13	9	40	27
950-1150	750	12	8	35	24
1000-1200	810	12	8	35	24
1050-1250	870	11	7	35	24
1100-1300	930	11	7	35	24

NOTE
For main propulsion shafting forgings, the minimum specified tensile strength is not to exceed 800 N/mm^2, *see* 3.4.9 (shaded area of Table).

3.4.9 Forgings in alloy steels may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.3.2, and minimum yield stress, elongation and reduction of area, obtained by interpolation, except that for main propulsion shafting forgings the specified minimum tensile strength is not to exceed 800 N/mm^2 (800–950 N/mm^2 acceptance range) *see* shaded area of Table 5.3.2.

3.4.10 The results of all tensile tests are to comply with the requirements given in Table 5.3.2 appropriate to the specified minimum tensile strength.

3.4.11 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 < 900	100
≥900	120

3.4.12 For screwshafts intended for ships with the notation **Ice Class 1AS** or **1A** and where the connection between the propeller and the screwshaft is by means of a key, a set of three Charpy V-notch impact tests (longitudinal test) is to be made on material from the propeller end of each shaft. The tests are to be carried out at –10°C and the average energy value is to be not less than 20 J.

3.5 Non-destructive examination

3.5.1 Magnetic particle or dye penetrant testing (where appropriate) is to be carried out on forgings for main propulsion shafting (including propeller shafts, intermediate shafts, and thrust shafts with minimum diameter not less than 100 mm), on all connecting rod forgings and on the following components when they are intended for engines having a bore diameter larger than 400 mm:

- Cylinder covers
- Piston crowns
- Piston rods
- Tie rods
- Gear wheels for camshaft drives
- Bolts and studs for:
  - Cylinder covers
  - Crossheads
  - Main bearings
  - Connecting rod bearings
  - Propeller blade fastening bolts
  - Crankpin bolts
  - Tie rod bolts
  - Additionally, bolts for engine bore diameters of less than 400 mm but having a minimum diameter 50 mm or greater (which are subjected to dynamic stress), are also to be subjected to surface examinations.

3.5.2 The areas to be tested by magnetic particle or dye penetrate testing are shown in Fig. 5.3.4 and Fig. 5.3.5. Areas of other components not shown in these figures are to be agreed with the Surveyor. For tie rods, only threaded portions and the adjacent material over a length equal to that of the thread need be tested.

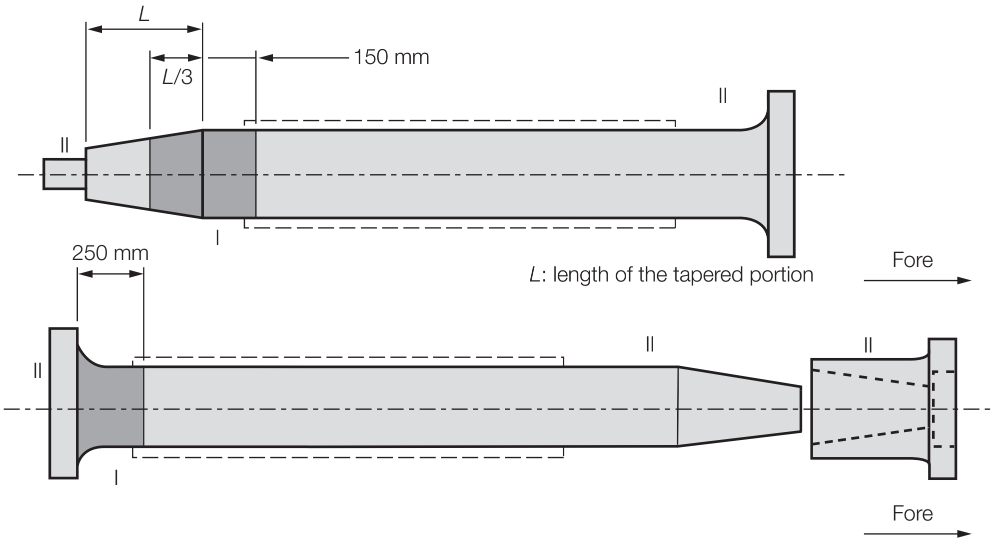
3.5.3 Surface inspection acceptance criteria are to be in accordance with 2.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.

3.5.4 Ultrasonic testing is to be carried out in accordance with 2.5 on the following items:

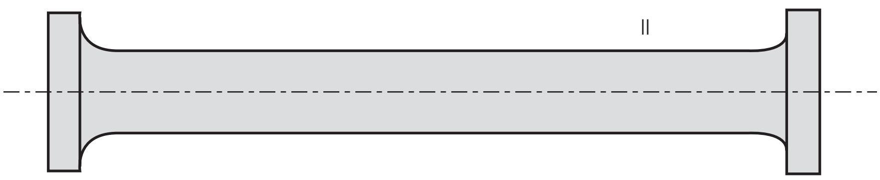
(a) Shafts having a finished diameter of 200 mm or larger when intended for main propulsion or other essential services.
(b) All piston crowns and cylinder covers.
(c) Piston rods and connecting rods for engines having a bore diameter greater than 400 mm.

The areas to be tested are shown in Fig. 5.3.6 and Fig. 5.3.7. Areas of other components not shown in these drawings are to be agreed with the Surveyor.

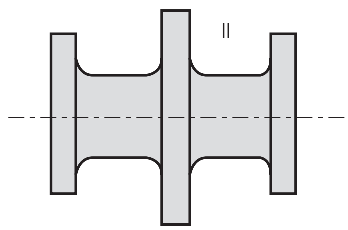
3.5.5 Ultrasonic acceptance criteria are shown in Table 5.3.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and are to the satisfaction of the Surveyor.



(a) Propeller shaft



(b) Intermediate shaft



(c) Thrust shaft

NOTE
For propeller shaft, intermediate shafts and thrust shafts, all areas with stress raisers such as radial holes, slots and key ways are to be treated as Zone I.

Fig. 5.3.4 Zones for magnetic particle/dye penetrant testing on machinery components

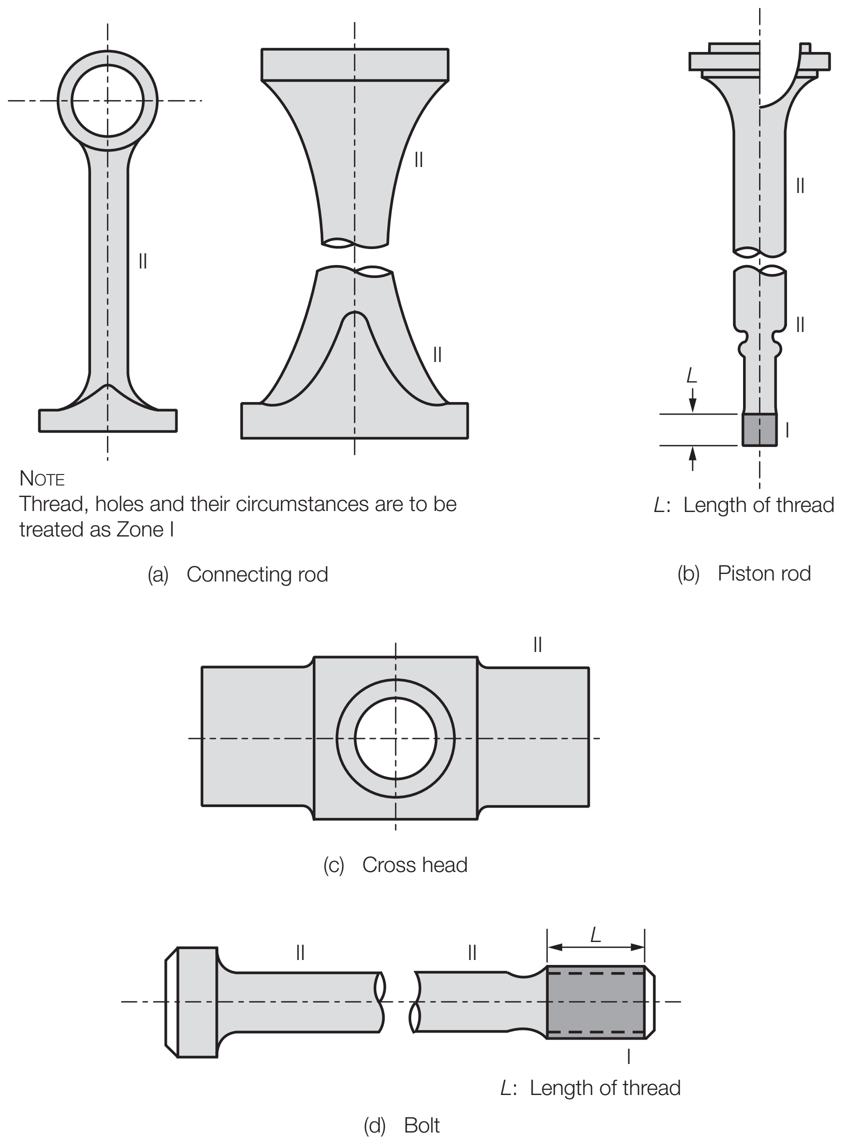
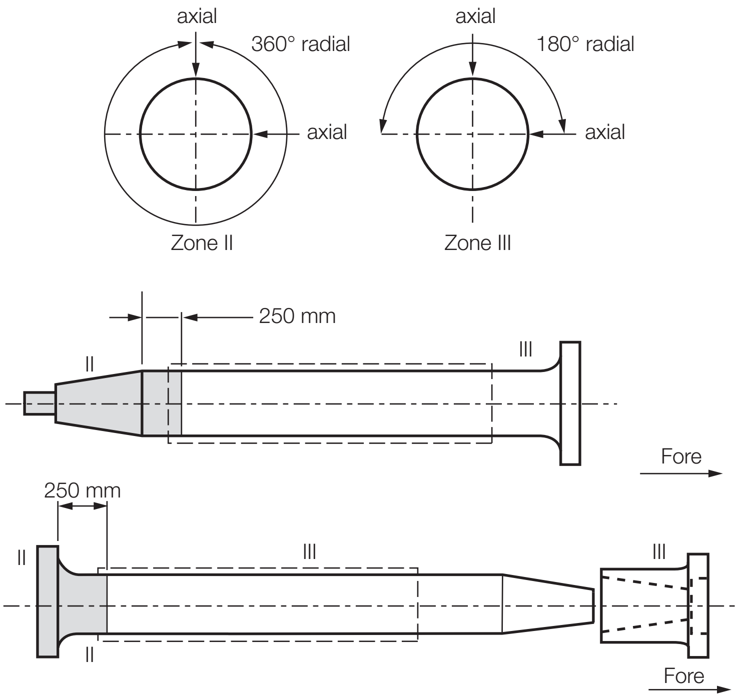
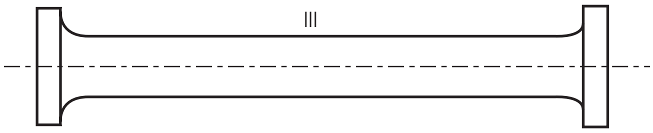


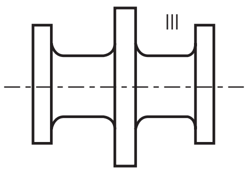
Fig. 5.3.5 Zones for magnetic particle/dye penetrant testing on machinery components



(a) Propeller shaft



(b) Intermediate shaft



(c) Thrust shaft

NOTES
1. For hollow shafts, 360° radial scanning applies to Zone III
2. Circumferences of the bolt holes in the flanges are to be treated as Zone II

Fig. 5.3.6 Zones for ultrasonic testing on shafts

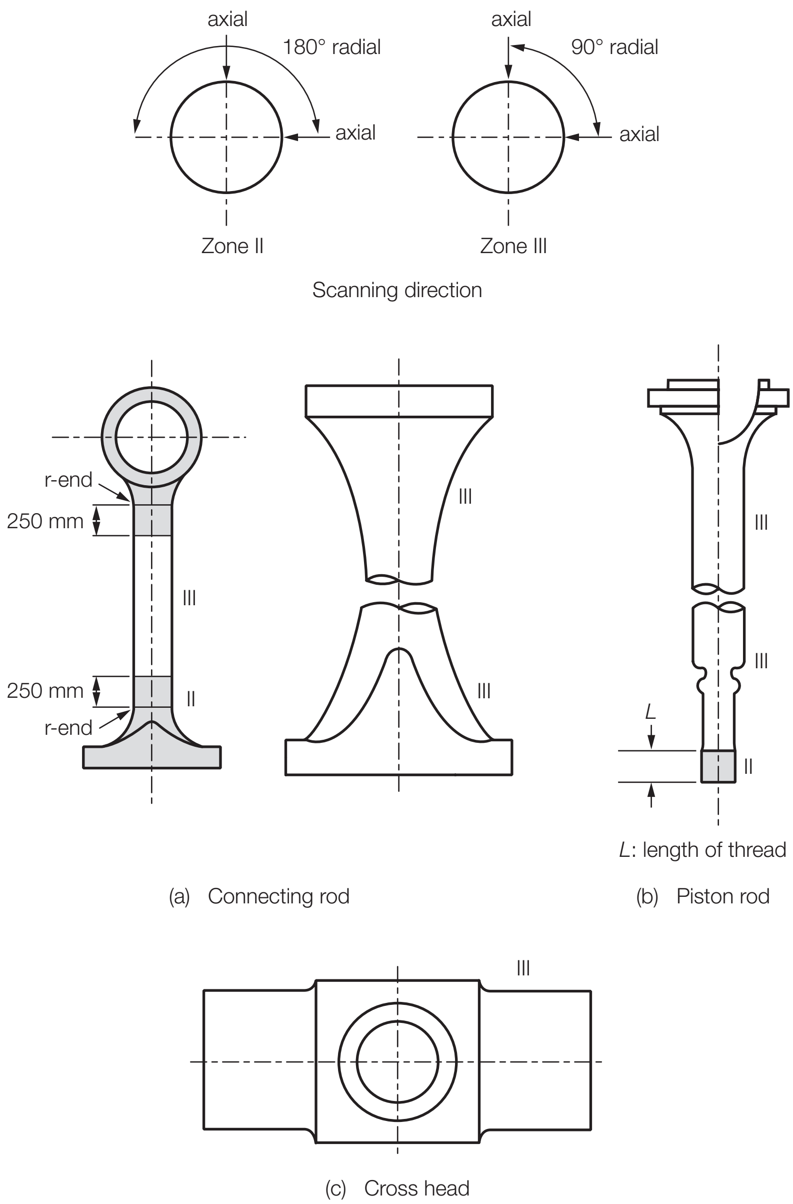


Fig. 5.3.7 Zones for ultrasonic testing on machinery components

Table 5.3.4 Acceptance criteria for ultrasonic testing

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), *see* Note 1, mm	Allowable length of indication, mm *see* Note 2
Propeller shaft Intermediate shaft	II	Outer $d \leq 2$ Inner $d \leq 4$	≤10 ≤15
Thrust shaft Rudder stock	III	Outer $d \leq 3$ Inner $d \leq 6$	≤10 ≤15
Connecting rod Piston rod	II	$d \leq 2$	≤10
	III	$d \leq 4$	≤10

NOTES
1. Outer part means the part beyond one third of the shaft radius from the centre. The inner part means the remaining core area.
2. For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication.

■ *Section 4*
Forgings for crankshafts

4.1 Scope

4.1.1 The specific requirements for solid forged crankshafts and forgings for use in the construction of fully built and semi-built crankshafts are detailed in this Section.

4.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition (*see* 1.4.3), heat treatment and mechanical properties are to be submitted for approval. The specified minimum tensile strength is not to exceed 1000 N/mm^2 (1000–1200 N/mm^2 acceptance range).

4.2 Manufacture

4.2.1 For closed die and continuous grain flow crankshafts forgings, where an allowance is given for design purposes, full details of the proposed method of manufacture are to be submitted for approval. In such cases, tests will be required to demonstrate that a satisfactory structure and grain flow are obtained. The number and positions of test specimens are to be agreed with LR.

4.2.2 For the manufacture of welded crankshafts, approval is required for the welding procedure.

4.2.3 For combined crankweb and pin forgings, the proposed method of forging is to be submitted for approval. It is recommended that these forgings be made by a folding method. Other methods which can be shown to produce sound forgings with satisfactory mechanical properties will be considered, but where the gapping method is used for cranks having a pin diameter exceeding 510 mm this will only be accepted provided that an upsetting operation is included in the manufacturing sequence. In general, the amount of work during the upsetting operation is to be such that the reduction in the original length of the ingot (after discard) or bloom is not less than 50 per cent.

4.2.4 Where crankwebs are flame cut from forged or rolled slabs, the procedure used is to be in accordance with 1.2.13, and additionally, unless specially agreed, a depth of at least 7,5 mm is to be removed by machining from all flame-cut surfaces.

4.3 Chemical composition

4.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

4.3.2 For alloy steel forgings which are to be nitrided, the phosphorus or sulphur contents are not to exceed 0,02 per cent.

4.4 Heat treatment

4.4.1 For forgings in all types of steels, heat treatment is to be either:
(a) normalising and tempering, or
(b) quenching and tempering.
The temperature used for tempering is to be not less than 550°C.

4.4.2 Where it is proposed to surface harden crankshaft forgings by nitriding or induction hardening, full details of the proposed procedure are to be submitted as required by 1.5.6.

4.5 Mechanical tests

4.5.1 At least one tensile test specimen is to be taken from each forging.

4.5.2 For solid forged crankshafts, tests are to be taken in the longitudinal direction from the coupling end of each forging (test position A in Fig. 5.4.1). Where the mass, as heat treated but excluding test material, exceeds 3 tonnes, a second set of tests is to be taken from the end opposite the coupling, in addition (test position B in Fig. 5.4.1). Where the crankthrows are formed by machining or flame cutting, the second set of tests is to be taken in a tangential direction from material removed from the crankthrow at the end opposite the coupling (test position C in Fig. 5.4.1).For continuous grain flow (CGF) crankshaft forgings, where insufficient material exists for a second longitudinal test, the second set of tests may be taken in a tangential direction from the crankthrow (test position C in Fig. 5.4.2).

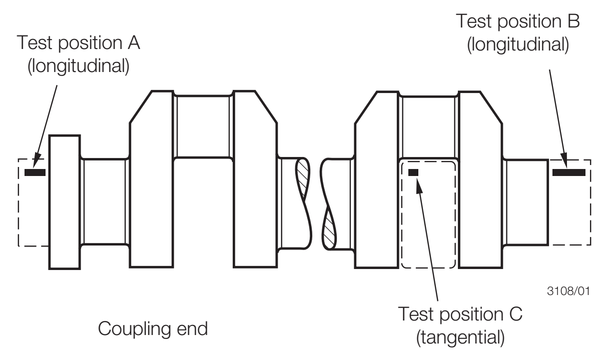


Fig. 5.4.1 Solid forged crankshaft

4.5.3 The number and position of test specimens from combined crankweb and pin forgings are to be in accordance with the requirements of the approved method of manufacture.

4.5.4 For other crankshaft forgings, tests are to be taken as detailed in Section 3, except that for crankwebs the test specimens are to be cut in a tangential direction.

4.5.5 As an alternative to 4.5.2, small solid forged crankshafts may be batch tested in accordance with 1.6.4, provided that, in addition, hardness tests are carried out on each forging.

4.5.6 Tables 5.4.1 to 5.4.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.4.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for crankshafts

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
400–520	200	26	19	110–150
440–560	220	24	18	125–160
480–600	240	22	16	135–175
520–640	260	21	15	150–185
560–680	280	20	14	160–200
600–750	300	18	13	175–215
640–790	320	17	12	185–230
680–830	340	16	12	200–240
720–870	350	15	11	210–250
760–910	380	14	18	225–265

Intermediate values may be obtained by interpolation.

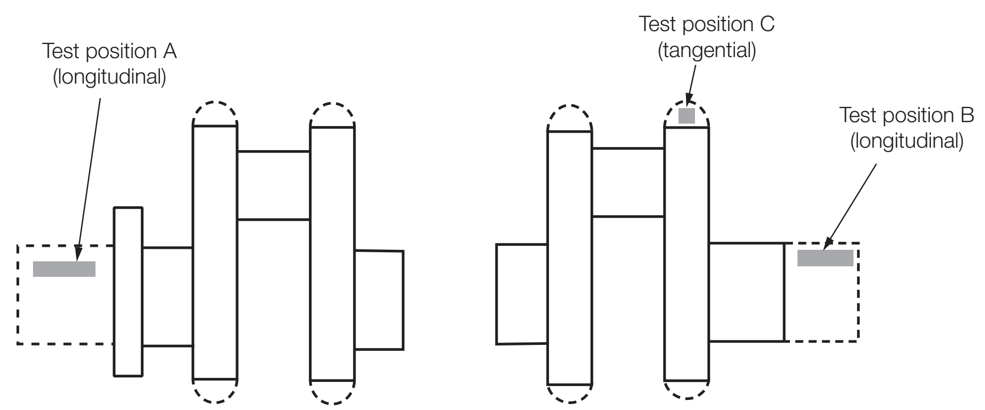


Fig. 5.4.2 CGF Crankshaft

Table 5.4.2 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	330	18	14	175–215
650–800	355	17	13	190–235
700–850	380	16	12	205–245
750–900	405	15	11	215–260
800–950	430	14	10	235–275
Intermediate values may be obtained by interpolation.				

Table 5.4.3 Mechanical properties for acceptance purposes: alloy steel forgings for crankshafts – Quenched and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum		Hardness Brinell
		Long.	Tang.	
600–750	420	18	14	175–215
650–800	450	17	13	190–235
700–850	480	16	12	205–245
750–900	530	15	11	215–260
800–950	590	14	10	235–275
850–1000	640	13	9	245–290
900–1100	690	13	9	260–320
950–1150	750	12	8	275–340
1000–1200	810	12	8	290–365
Intermediate values may be obtained by interpolation.				

4.5.7 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.4.1 to 5.4.3.

4.5.8 The results of all tensile tests are to comply with the requirements of Table 5.4.1, 5.4.2 or 5.4.3 appropriate to the specified minimum tensile strength.

4.5.9 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

4.5.10 For small crankshaft forgings which have been batch tested, the hardness values are to be not less than those given in Tables 5.4.1 to 5.4.3, as appropriate. The variation in hardness in each batch is to comply with the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	not more than 25
≥600 <900	not more than 35
≥900	not more than 42

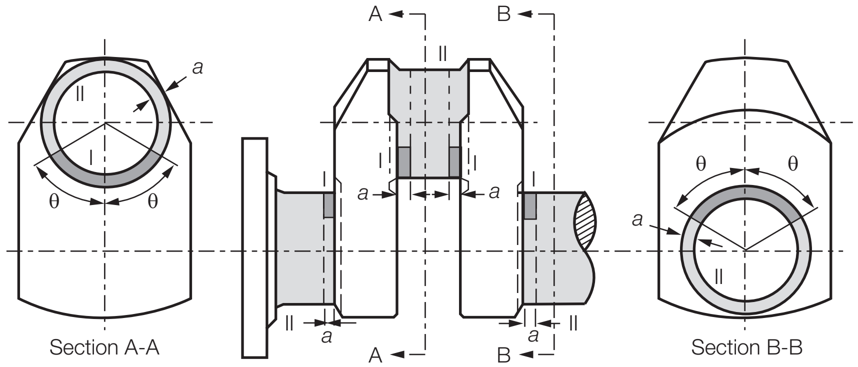
4.6 Non-destructive examination

4.6.1 Magnetic particle or dye penetrant testing as detailed in 1.8.5 and 2.5 is to be carried out on all forgings for crankshafts. Where applicable, this is to include all surfaces which have been flame-cut, but not subsequently machined during manufacture. Particular attention is to be given to the testing of the pins, journals and associated fillet radii of solid forged crankshafts and to the pins and fillet radii of combined web and pin forgings. The extent of testing is shown in Fig. 5.4.3.

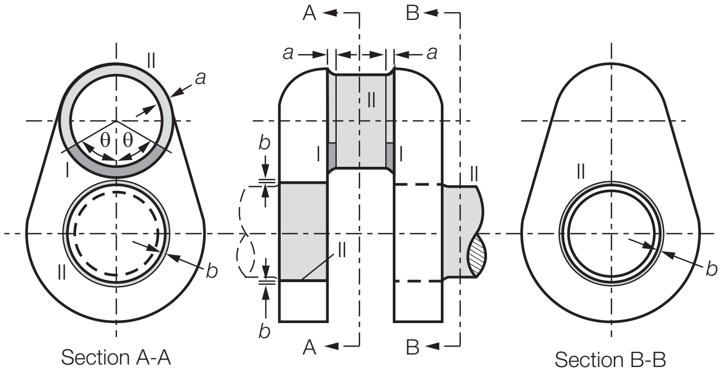
4.6.2 The manufacturer is to carry out an ultrasonic examination of all forgings as detailed in 1.8.8 and 2.5, except that for closed-die forgings this examination may, subject to approval, be confined to the initial production and to subsequent occasional checks. The extent of ultrasonic testing is shown in Fig. 5.4.4.

4.6.3 Surface inspection acceptance criteria are to be in accordance with 2.5 and with Table 5.4.4. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.

4.6.4 Ultrasonic acceptance criteria are shown in Table 5.4.5. Other acceptance criteria may be applied, providing they meet these minimum criteria, and is to the satisfaction of the Surveyor.



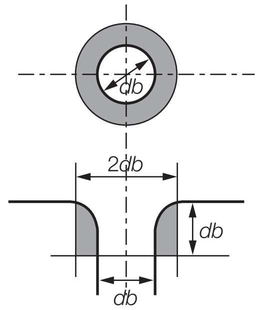
(a) Soild crankshaft



(b) Semi built-up crankshaft

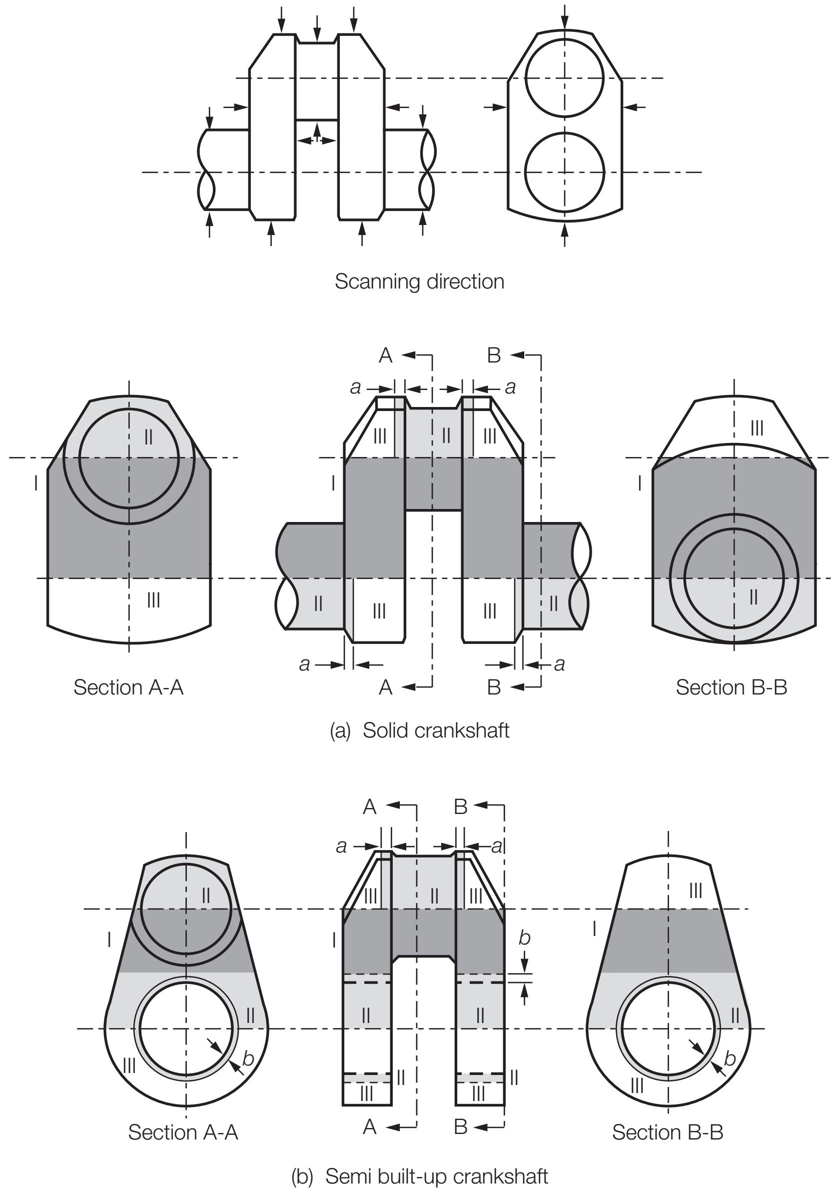
NOTES

1. Where the crankpin or journal has oil holes, the circumferential surfaces of the oil are to be treated as Zone I, (*see* the figure on the right)
2. In the above figures:
   θ = 60°
   a = 1,5*r*
   b = 0,05*d* (: circumferential surfaces of shrinkage fit)
   where
   r : fillet radius
   d : journal diameter
3. Identification of the Zones:
   : Zone I
   : Zone II



db: Oil hole bore diameter

Fig. 5.4.3 Zones for magnetic particle/dye penetrant testing on crankshafts



NOTES
1. In the above figures:
   a = 0,1*d* or 25 mm, whichever is greater
   b = 0,05*d* or 25 mm, whichever is greater (: circumstances of shrinkage fit)
   where
   d : pin or journal diameter
2. The mid third area of crank pins and/or journals within a raduis of 0,25*d* between the webs may generally be coordinated to Zone II
3. Identification of the Zones:
   : Zone I
   : Zone II
   : Zone III

Fig. 5.4.4 Zones for ultrasonic testing on crankshafts

Table 5.4.4 Surface inspection acceptance for crankshaft forgings – Allowable number and size of indications in a reference area of 225 cm^2

Inspection zone	Maximum number of indication	Type of indication	Maximum number each type	Maximum dimension of single indication, mm
I Critical fillet area	0	Linear Non-linear Aligned	0 0 0	— — —
II Important fillet area	3	Linear Non-linear Aligned	0 3 0	— 3,0 —
III Journal surfaces	3	Linear Non-linear Aligned	0 3 0	— 5,0 —

Table 5.4.5 Ultrasonic acceptance criteria for crankshafts

Type of forging	Zone	Allowable disc shape according to Distance Gain Size (DGS), mm	Allowable length of indication, mm *see* Note
Crank shaft	I II III	$d \leq 2,0$ $d \leq 3,0$ $d \leq 4,0$	— ≤10 ≤15

NOTE
For accumulations of two or more isolated indications which are subjected to registration, the minimum distance between two neighbouring indications is to be at least the length of the larger indication. This applies to the distance in axial direction as to the distance in depth. Isolated indications with less distance are to be determined as one single indication.

■ *Section 5* Forgings for gearing

5.1 Scope

5.1.1 Provision is made in this Section for carbon-manganese and alloy steel forgings intended for use in the construction of gearing for main propulsion and for driving electric generators.

5.1.2 Gear wheel and rim forgings with a specified minimum tensile strength not exceeding 760 N/mm^2 (760–910 N/mm^2 acceptance range) may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings, are to be made in a suitable alloy steel. Specifications for alloy steel components and for quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval.

5.1.3 Forgings for flexible couplings, quill shafts and gear wheel shafts are to comply with the requirements of Section 3.

5.1.4 Manufacturers' test certificates for forgings may be accepted where the transmitted power does not exceed 220 kW (300 shp) for main propulsion and 100 kW (150 shp) for auxiliary drives.

5.2 Manufacture

5.2.1 All forgings are to be made with sufficient material to allow an adequate machining allowance on all surfaces for the removal of unsound or decarburised material.

5.2.2 The hardenability of the forged material is to be checked at random intervals using an end quench test complying with a National or International Standard.

5.2.3 The grain size is to be checked on a random basis in accordance with the testing and reporting procedures of ASTM E 112, or an equivalent National Standard, and is to be within the range 5 to 8.

5.2.4 The microstructure of the hardened case is to be mainly martensite, with a maximum content of 15 per cent of retained austenite.

5.3 Chemical composition

5.3.1 The chemical composition of ladle samples is to comply with 3.2.1. for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

5.4 Heat treatment

5.4.1 Except as provided in 5.4.4 and 5.4.5, forgings may be either normalised and tempered or quenched and tempered in accordance with the approved specification. The tempering temperature is to be not less than 550°C.

5.4.2 Where forgings are machined prior to heat treatment, the allowance left for final machining is to be sufficient to remove the decarburised surface material, taking into account any bending or distortion which may occur.

5.4.3 When the teeth of a pinion or gear wheel are to be surface hardened, i.e, carburised, nitrided or induction hardened, the proposed specification together with details of the process and practice are to be submitted for approval. For purposes of initial approval, the gear manufacturer is required to demonstrate by test that the surface hardening of the teeth is uniform and of the required depth and that it does not impair the soundness and quality of the steel.

5.4.4 Where induction hardening of nitriding is to be carried out after machining of the gear teeth, the forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

5.4.5 Forgings for gears which are to be carburised after final machining are to be supplied in either the fully annealed or the normalised and tempered condition, suitable for subsequent machining and carburising.

5.5 Mechanical tests for through hardened, induction hardened or nitrided forgings

5.5.1 At least one tensile test specimen is to be taken from each forging in carbon or carbon-manganese steel, and at least one tensile test specimen from forgings in alloy steel. Sufficient test material is to be provided for this purpose and the test specimens are to be taken as follows:

(a) For pinion forgings where the finished diameter of the toothed portion exceeds 200 mm, tests are to be taken in a tangential direction and adjacent to the toothed portion (test position B in Fig. 5.5.1). Where the dimensions preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test position C in Fig. 5.5.1). If, however, the journal diameter is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1). Where the finished length of the toothed portion exceeds 1250 mm, tests are to be taken from each end.

(b) For small pinion forgings where the finished diameter of the toothed portion is 200 mm or less, tests are to be taken in a longitudinal direction (test position A in Fig. 5.5.1).

(c) For gear wheel forgings, tests are to be taken in a tangential direction (from one of the test positions B in Fig. 5.5.2).

(d) For gear wheel rim forgings, tests are to be taken in a tangential direction (from one of the test positions A in Fig. 5.5.3). Where the finished diameter exceeds 2500 mm or the mass (as heat treated but excluding test material) exceeds 3 tonnes, tests are to be taken from two diametrically opposite positions (test positions A in Fig. 5.5.3).

(e) For pinion sleeve forgings, tests are to be taken in a tangential direction (from one of the test positions C in Fig. 5.5.4). Where the finished length exceeds 1250 mm, tests are to be taken from each end.

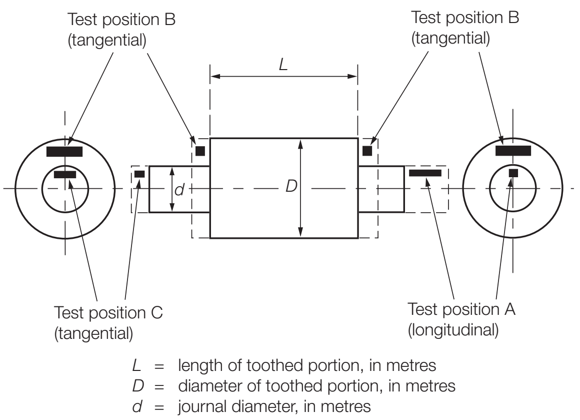


Fig. 5.5.1 Test positions for forgings for gearing

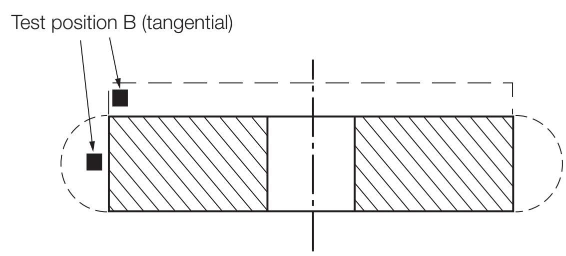


Fig. 5.5.2 Test position B

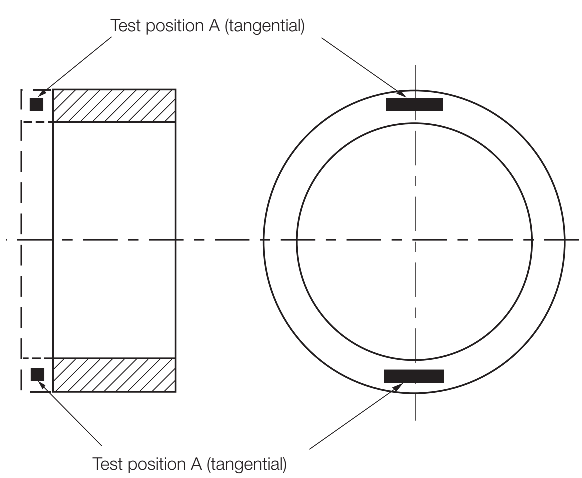


Fig. 5.5.3 Test position A

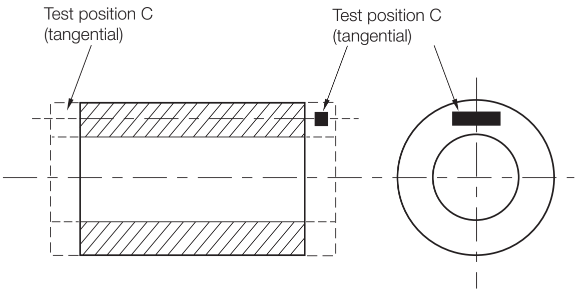


Fig. 5.5.4 Test position C

5.5.2 As an alternative to 5.5.1, small forgings may be batch tested in accordance with 1.6.4 provided that, in addition, hardness tests are carried out on each forging.

5.5.3 Tables 5.5.1 to 5.5.3 give the minimum requirements for yield stress and elongation corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 in the case of alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.5.1 Mechanical properties for acceptance purposes: carbon-manganese steels for gear wheel and rim forgings

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
400–520	200	26	22	110–150
440–560	220	24	21	125–160
480–600	240	22	19	135–175
520–640	260	21	18	150–185
560–680	280	20	17	160–200
600–750	300	18	15	175–215
640–790	320	17	14	185–230
680–830	340	16	14	200–240
720–870	360	15	13	210–250
760– 910	380	14	12	225–265

Intermediate values may be obtained by interpolation.

NOTE
When the specified minimum tensile strength exceeds 700 N/mm^2 forgings are to be supplied only in the quenched and tempered condition.

5.5.4 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 5.5.1 to 5.5.3.

5.5.5 The results of all tensile tests are to comply with the requirements of Table 5.5.1, 5.5.2 or 5.5.3, appropriate to the specified minimum tensile strength. Unless otherwise agreed, the specified minimum tensile strength is to be not less than 800 N/mm^2 (800–950 N/mm^2 acceptance range) for induction hardened or nitrided gear forgings.

Table 5.5.2 Mechanical properties for acceptance purposes: alloy steel gear wheel and rim forgings – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation on $5,65\sqrt{S_o}$ % minimum		Hardness Brinell
		Rims	Wheels	
600–750	330	18	16	175–215
650–800	355	17	15	190–235
700–850	380	16	14	205–245
750–900	405	15	13	215–260
800–950	430	14	12	235–275
850–1000	455	13	11	245–290

Intermediate values may be obtained by interpolation.

Table 5.5.3 Mechanical properties for acceptance purposes: alloy steel gear forgings – Quenched and tempered

Tensile strength N/mm^2 (*see* Notes 1 and 2)	Yield stress N/mm^2 minimum (*see* Note 2)	Elongation on $5,65\sqrt{S_o}$ % minimum			Hardness Brinell
		A	B	C	
600–750	420	18	16	14	175–215
650–800	450	17	15	13	190–235
700–850	480	16	14	12	205–245
750–900	530	15	13	11	215–260
800–950	590	14	12	10	235–275
850–1000	640	13	11	9	245–290
900–1050	690	13	11	9	260–310
950–1100	750	12	10	8	275–330
1000–1150	810	12	10	8	290–340
1050–1200	870	11	9	7	310–365

Column A is applicable to tests from gear rims and to longitudinal tests from pinions.
Column B is applicable to tests from gear wheels and to tangential tests from pinions.
Column C is applicable to tests from pinion sleeves.

Intermediate values may be obtained by interpolation.

NOTES
1. For gear wheel and rim forgings the specified minimum tensile strength is not to exceed 850 N/mm^2.
2. For carburised gear forgings the requirements for minimum yield stress and maximum tensile strength are not applicable.

5.5.6 Where more than one tensile test is taken from a forging, the variation in tensile strength is not to exceed the following:

Specified minimum tensile strength N/mm^2	Difference in tensile strength N/mm^2
<600	70
≥600 <900	100
≥900	120

5.5.7 Hardness tests are to be carried out on all forgings after completion of heat treatment and prior to machining the gear teeth. The hardness is to be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2500 mm, the number of test positions is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1250 mm, the hardness is to be determined at eight positions at each end of the forging.

5.5.8 For small gear forgings which are batch tested, at least one hardness test is to be carried out on each forging.

5.5.9 The results of all hardness tests are to comply with the appropriate requirements of Tables 5.5.1 to 5.5.3. The difference between the highest and lowest values on any one forging is not to exceed the following:

Specified minimum tensile strength (N/mm^2)	Difference in hardness (Brinell number)
<600	25
≥600 <900	35
≥900	42

5.5.10 On nitrided or induction hardened components, hardness tests are also to be made on the teeth when surface hardening and grinding have been completed. The results are to comply with the approved specification.

5.6 Mechanical tests for carburised forgings

5.6.1 Sufficient test material is to be provided for preliminary tests at the forge and for final tests after completion of carburising. For this purpose, duplicate sets of test material are to be taken from positions as detailed in 5.5.1, except that, irrespective of the dimensions or mass of the forging, tests are required from one position only, and in the case of forgings with integral journals are to be cut in a longitudinal direction. The test material which is to be used for measurements of case depth, hardness, grain size and residual austenite as well as mechanical properties is to be machined to a coupon of diameter of $\frac{D}{4}$ or 30 mm, whichever is less, where *D* is the finished diameter of the toothed portion.

5.6.2 For small forgings, where a system of batch testing is adopted, the test material may be prepared from surplus steel from the same cast provided that the forging reduction approximates to that of the actual gear forgings. The test samples are to be correctly identified and heat treated with the forgings they represent.

5.6.3 For preliminary tests at the forge, one set of test material is to be given a blank carburising and heat treatment cycle simulating that which will be subsequently applied to the forgings.

5.6.4 For final acceptance tests, the second set of test material is to be blank carburised and heat treated together with the forgings which it represents.

5.6.5 At the discretion of the forgemaster or gear manufacturer, test samples of larger cross-section than in 5.6.1 may be either carburised or blank carburised, but these are to be machined to the required diameter prior to the final quenching and stress relieving heat treatment.

5.6.6 At least one tensile specimen is to be prepared from each sample of test material.

5.6.7 Unless otherwise agreed, the specified minimum tensile strength is to be not less than 750 N/mm^2, and the results of all tensile tests are to comply with the requirements given in Table 5.5.3.

5.6.8 Where it is proposed to adopt alternatives to the requirements of 5.6.1 to 5.6.7, full details are to be submitted to the Surveyor for consideration.

5.7 Non-destructive examination

5.7.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.7.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

5.7.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, (i.e., depth to core hardness), is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 HV.

■ *Section 6*
Forgings for turbines

6.1 Scope

6.1.1 Provision is made in this Section for ferritic steel forgings for turbine rotors, discs and spindles, turbine-driven generator rotors and compressor rotors.

6.1.2 Plans for rotor forgings are to state whether the rotor is intended for propulsion or auxiliary machinery and the shaft power of auxiliary turbines. In the case of a rotor which is to be tested for thermal stability, the maximum operating temperature and the proposed test temperature are also to be stated.

6.1.3 Specifications of alloy steel forgings giving the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval with the plans of the components.

6.1.4 Where it is proposed to use rotors of welded construction, the compositions of the steels for the forgings are to be submitted for special consideration, together with details of the proposed welding procedure. Welding procedure tests may be required.

6.2 Manufacture

6.2.1 Forgings are to be manufactured in accordance with the requirements of Section 1, except that for rotors the forging reduction is to be not less than 2,5 to 1. Where an upsetting operation is included in the manufacturing procedure, the above requirement applies to the cross-sectional area of the upset bloom and not to that of the ingot.

6.3 Chemical composition

6.3.1 The chemical composition of ladle samples is to comply with 3.2.1 for carbon and carbon-manganese steels and 1.4.3 for alloy steels.

6.4 Heat treatment

6.4.1 Forgings are to be supplied in the heat treated condition, and the thermal treatment at all stages is to be such as to avoid the formation of hair-line cracks. At a suitable stage of manufacture, the forgings are to be reheated above the upper critical point to refine the grain, cooled in an approved manner and then tempered to produce the desired mechanical properties.

6.4.2 Where forgings receive their main heat treatment before machining, they are to be stress relieved after rough machining. Forgings which are heat treated in the rough machined condition need not be stress relieved provided that they have been slowly cooled from the tempering temperature.

6.4.3 The tempering and stress relieving temperatures are to be not less than 550°C for carbon and carbon-manganese steels, and not less than 600°C for alloy steels. The holding times and subsequent cooling rates are to be such that the forging in its final condition is free from harmful residual stresses.

6.4.4 Details of the proposed heat treatment for rotors of welded construction are to be submitted for approval.

6.5 Mechanical tests

6.5.1 At least one tensile test specimen, cut in a longitudinal direction, is to be taken from each rotor forging. For forgings exceeding both 3 tonnes in mass and 2000 mm in length, tests are to be taken from each end.

6.5.2 For rotor forgings of all main propulsion machinery and of auxiliary turbines exceeding 1100 kW, tangential and, where the dimensions permit, radial tensile tests are to be taken from the end of the body corresponding to the top end of the ingot, *see* Fig. 5.6.1.

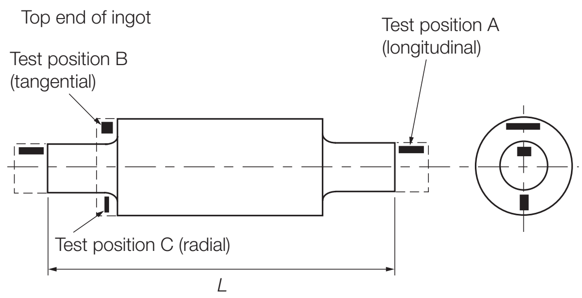


Fig. 5.6.1 Test positions for turbine rotor forgings

6.5.3 For each turbine disc, at least one tensile test specimen is to be cut in a tangential direction from material at the hub, *see* Fig. 5.6.2.

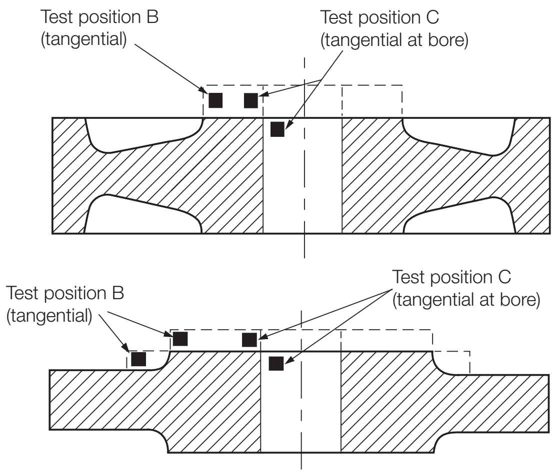


Fig. 5.6.2 Test positions for turbine disc forgings

6.5.4 For the tests required by 6.5.1 to 6.5.3, sufficient test material is to be left on each forging and is not to be removed until all heat treatment, including stress relieving, has been completed. In this connection, a thermal stability test does not form part of the heat treatment of a turbine forging. Any excess test material is not to be completely severed from a forging until all the mechanical tests have been completed with satisfactory results.

6.5.5 Tables 5.6.1 and 5.6.2 give the minimum requirements for yield stress, elongation and reduction of area corresponding to different strength levels, but it is not intended that these should necessarily be regarded as specific grades. The strength levels have been given in multiples of 40 N/mm^2, or 50 N/mm^2 for alloy steels, to facilitate interpolation for intermediate values of specified minimum tensile strength.

Table 5.6.1 Mechanical properties for acceptance purposes: carbon-manganese steel forgings for turbines – Normalised and tempered

Tensile strength N/mm^2	Yield stress N/mm^2 minimum	Elongation $5{,}65\sqrt{S_o}$ % minimum			Reduction of area % minimum		
		A	B	C	A	B	C
400–520	200	26	22	18	50	40	35
440–560	220	24	21	17	50	40	35
480–600	240	22	19	15	45	35	30
520–640	260	21	18	14	45	35	30
560–680	280	20	17	13	40	30	25
600–720	300	18	15	12	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor forgings.
Columns C are applicable to radial tests from rotor forgings.
Intermediate values may be obtained by interpolation.

6.5.6 Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Table 5.6.1 or Table 5.6.2.

6.5.7 The results of all tensile tests are to comply with the requirements of Table 5.6.1 or Table 5.6.2 appropriate to the specified minimum tensile strength. For monobloc rotor forgings, the specified minimum tensile strength is not to exceed 800 N/mm^2.

6.6 Non-destructive examination

6.6.1 The end faces of the body of rotor forgings and the end faces of the boss and the bore surface of each turbine disc are to be machined to a fine smooth finish for visual and magnetic particle examination.

6.6.2 The manufacturer is to carry out an ultrasonic examination of each forging and is to provide the Surveyor with a signed statement that such inspection has not revealed any significant internal defects.

6.6.3 Rotor forgings for propulsion machinery and for auxiliary turbines exceeding 1100 kW are to be hollow bored for internal examination. The surface of the bore is to have a fine smooth finish and is to be examined by means of an optical instrument of suitable magnification. Where the bore size permits, magnetic particle examination is also to be carried out. These examinations are to be confirmed by the Surveyor. Alternatively, an approved method of ultrasonic examination may be accepted instead of hollow boring. Details of the proposed method of ultrasonic examination are to be submitted for special consideration.

Table 5.6.2 Mechanical properties for acceptance purposes: alloy steel forgings for turbines – Quenched and tempered or normalised and tempered

Tensile strength N/mm^2 (*see* Note)	Yield stress N/mm^2 minimum Normalised and tempered	Yield stress N/mm^2 minimum Quenched and tempered	Elongation on $5{,}65\sqrt{S_o}$ % minimum			Reduction of area %minimum		
			A	B	C	A	B	C
500 – 650	275	—	22	20	18	50	40	35
550 – 700	300	—	20	18	16	50	40	35
600 – 750	330	410	18	16	14	50	40	35
650 – 800	355	450	17	15	13	50	40	35
700 – 850	385	490	16	14	12	45	35	30
750 – 900	—	530	15	13	11	45	35	30
800 – 950	—	590	14	12	10	45	35	30
850 – 1000	—	640	13	11	9	40	30	25
900 – 1050	—	690	13	11	9	40	30	25
950 – 1100	—	750	12	10	8	40	30	25
1000 – 1150	—	810	12	10	8	40	30	25

NOTES
Columns A are applicable to longitudinal tests from rotor and spindle forgings.
Columns B are applicable to tangential tests from rotor and spindle forgings, and to tangential tests from discs – test position B in Fig. 5.6.2.
Columns C are applicable to radial test from rotor forgings and to tangential tests from discs – test position C in Fig. 5.6.2.
Intermediate values may be obtained by interpolation.

6.7 Thermal stability tests

6.7.1 Thermal stability tests after heat treatment and rough machining of the turbine rotors, referred to in the relevant Rules dealing with design and construction, are to be undertaken in properly constructed furnaces, using accurate and reliable measuring equipment. Each test is to be carried out in accordance with the following recommended procedure:

(a) Five bands are to be machined concentric with the axis of rotation. Two of these are to be reference bands and are to be positioned at or near the locations of the bearings. The remaining three bands are to be test bands located one as near as possible to the mid-length, and the other two near each end of the body. Where the length of a rotor is such that five bands cannot be provided, alternative proposals are to be submitted to the Surveyor for his approval.

(b) Four positions, 90° apart, are to be stamped A, B, C and D on the coupling end of the rotor.

(c) The whole of the body, and as much of the shaft at either end as will include the positions of the glands, is to be enclosed in the furnace. In the case of a rotor having an overhung astern wheel, the astern wheel is also to be enclosed in the furnace during the first test.

(d) The rotor is to be rotated at a uniform and very low speed.

(e) The deflections at all bands are to be recorded at the A, B, C and D positions. Initial cold readings are to be taken prior to heating.

(f) The rotor is to be heated uniformly and slowly. Temperatures are to be recorded continuously at the surface of the rotor and, if practicable, in the bore at the mid-length of the body. In no circumstances is the surface temperature to exceed the temperature at which the rotor was tempered. During heating, the rate of rise of temperature is to be such as to avoid excessive temperature gradients in the rotor.

(g) The maximum or holding temperature is to be not less than 28°C above the maximum operating temperature of the rotor. For the purposes of the test, the holding period is to start when the rotor has attained a uniform and specified temperature. The rotor is to be held under the specified temperature conditions until not less than three consecutive hourly readings of deflections show the radial eccentricity to be constant within 0,006 mm on all test bands.

(h) The turbine rotor is to be rotated during cooling until the temperature is not more than 100°C. The rate of cooling is to be such as to avoid excessive temperature gradients in the rotor.

(j) Final cold readings are to be taken.

6.7.2 The movements of the axis of the rotor in relation to the reference bands are to be determined from polar plots of the deflection readings. The radial movement of the shaft axis, as determined by the difference between the final hot and the final cold movements, is not to exceed 0,025 mm on any one band. As verification that test equipment and conditions are satisfactory, it is required that similar determinations of differences between initial cold and final cold movements do not exceed 0,025 mm on any one band.

6.7.3 If the results of the test on a rotor fail to meet either or both of the requirements in 6.7.2, the test may be repeated if requested by the maker and agreed by the Surveyor. In the case of a rotor failing to meet the requirements of a thermal stability test, the rotor is deemed unacceptable. Proposals for the rectification of thermal instability of a rough machined rotor are to be submitted for special consideration.

■ *Section 7* **Forgings for boilers, pressure vessels and piping systems**

7.1 Scope

7.1.1 Provision is made in this Section for carbon-manganese and low alloy steel forgings intended for use in the construction of boilers, pressure vessels and piping systems where the design temperature is not lower than 0°C.

7.1.2 In addition to specifying mechanical properties at ambient temperature for the purposes of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

7.1.3 Forgings used in the construction of equipment for the containment of liquefied gases are to comply with the requirements of Section 8, except for those used in piping systems, where the design temperature is not lower than 0°C. Forgings for other pressure vessels and piping systems, where the use of steels with guaranteed impact properties at low temperatures is required, are also to comply with Section 8.

7.2 Chemical composition

7.2.1 The chemical composition of ladle samples is to comply with the appropriate requirements of Table 5.7.1.

7.3 Heat treatment

7.3.1 Carbon-manganese steel forgings are to be normalised, normalised and tempered or quenched and tempered.

7.3.2 Alloy steel forgings are to be normalised and tempered or quenched and tempered.

7.3.3 No forging is to be fully heat treated more than twice.

7.4 Mechanical tests

7.4.1 Except as provided in 7.4.2 and 7.4.4, at least one tensile test is to be taken from each forging and, where the dimensions and shape allow, the test specimen is to be cut in the longitudinal direction.

Table 5.7.1 Chemical composition

Type of steel	Tensile strength N/mm^2	Chemical composition of ladle samples %							
		C max.	Si	Mn	P max.	S max.	Al	Residual elements	
Carbon-manganese	410–530 460–580 490–610	0,20 0,23 0,25	0,10–0,40	0,50–1,20 0,80–1,40 0,90–1,70	0,030	0,025	(*See* Notes 1 and 3)	Ni 0,40 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,80 max.	
								Cr	Mo
Alloy steel 1Cr$^1/_2$Mo 2$^1/_4$ Cr1Mo	440–590 490–640	0,18 0,15	0,15–0,40	0,40–0,70	0,030	0,025	0,020 max. (*See* Note 2)	0,85–1,15 2,0–2,5	0,45–0,65 0,90–1,20

NOTES
1. Fine grained steels are to contain:
   aluminium (acid soluble) 0,015% min. or
   aluminium (total) 0,018% min.
2. For alloy steels, aluminium (acid soluble) 0,020% max.
   The determination of the aluminium (total) content is acceptable provided the above value is not exceeded.
3. Niobium may be used as a grain refiner in place of aluminium, in which case the content is to be in the range 0,01% to 0,06%.

7.4.2 On seamless drums and headers which are initially forged with open ends, test material is to be provided at each end of each forging. Where forged with one solid end, test material is to be provided at the open end only. Except where the ends are to be subsequently closed by forging, the test material is not to be removed until heat treatment has been completed. Where the ends are to be closed, rings of test material are to be cut off prior to the closing operation and are to be heat treated with the finished forging. In all cases, the test specimens are to be cut in the circumferential direction.

7.4.3 Unless otherwise agreed, tensile test specimens are to be taken with their axis at approximately 12,5 mm below the surface of the forging.

7.4.4 Small forgings may be batch tested in accordance with 1.6.4 provided that hardness tests are carried out on each forging. In such cases, the mass of each forging is not to exceed 1 tonne and that of the batch is not to exceed 10 tonnes and the hardness values are to accord with Table 5.7.2.

Table 5.7.2 Mechanical properties for acceptance purposes

Type of steel	Diameter or equivalent thickness mm	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Hardness Brinell
Carbon-manganese not specifically fine grained	≤100	215	410–530	20	110–155
	>100 ≤500	205			
	≤100	245	460–580	18	130–170
	>100	235			
	≤100	265	490–610	16	140–180
	>100	255			
Carbon-manganese, fine grained	≤100	235	410–530	20	110–155
	>100 ≤250	220			
	≤100	275	460–580	18	130–170
	>100 ≤250	255			
	≤100	305	490–610	16	140–180
	>100 ≤250	280			
Alloy steel 1Cr$^1/_2$Mo	–	275	440–590	19	110–160
2$^1/_4$Cr1Mo	–	275	490–640	18	140–185

7.4.5 If required by the Surveyors or by the Fabricators, test material may be given a simulated stress relieving heat treatment prior to the preparation of the test specimens. This has to be stated on the order, together with agreed details of the simulated heat treatment and the mechanical properties which can be expected.

7.4.6 Except as provided in 7.4.7, the results of all tensile tests are to comply with the requirements given in Table 5.7.2 appropriate to the specified minimum tensile strength.

7.4.7 Where tests are taken at a depth greater than 12,5 mm from the surface or where they are taken in a transverse direction, the mechanical properties which can be expected are to be agreed.

7.4.8 On seamless drums and headers where tests are taken from each end, the variation in tensile strength is not to exceed 70 N/mm^2.

7.4.9 For small batch-tested forgings, the hardness values are to comply with the requirements of Table 5.7.2 appropriate to the specified minimum tensile strength. If forgings of more than one thickness are to be supplied from one cast, then the test is to be made on the thickest forging.

7.5 Non-destructive examination

7.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

7.6 Pressure tests

7.6.1 Where applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

7.7 Mechanical properties for design purposes

7.7.1 Nominal values for the minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 5.7.3. These values are intended for design purposes only, and verification is not required except for materials complying with National or proprietary specifications where the elevated temperature properties used for design purposes are higher than those given in Table 5.7.3.

Table 5.7.3 Mechanical properties for design purposes

Type of steel	Diameter or equivalent thickness mm	Tensile strength N/mm^2	Nominal minimum lower yield or 0,2% proof stress N/mm^2											
			Temperature °C											
			50	100	150	200	250	300	350	400	450	500	550	600
Carbon-manganese not specifically fine grained	≤100	410–530	196	192	188	181	168	150	142	138	136	—	–	—
	>100		183	178	175	170	162	150	142	138	136	—	—	—
	≤100	460–580	227	222	218	210	194	176	168	162	158	—	—	—
	>100		212	206	203	197	188	176	168	162	158	—	—	—
	≤100	490–610	245	240	236	227	210	192	183	177	172	—	—	—
	>100		229	222	219	212	203	192	183	177	172	—	—	—
Carbon-manganese fine grained	≤100	410–530	222	215	204	188	171	152	141	134	130	—	—	—
	>100		207	200	190	175	164	152	141	134	130	—	—	—
	≤100	460–580	262	251	236	217	198	177	167	158	153	—	—	—
	>100		244	233	220	202	190	177	167	158	153	—	—	—
	≤100	490–610	286	272	256	234	213	192	182	173	168	—	—	—
	>100		266	253	238	218	205	192	182	173	168	—	—	—
Alloy steel 1Cr$^1/_2$Mo	—	410–560	254	241	224	213	197	184	170	162	157	151	146	145
2$^1/_4$ Cr1Mo	—	490–640	268	261	253	245	236	230	224	218	205	189	167	145

7.7.2 Where verification is required, at least one tensile test at the proposed design or other agreed temperature is to be made on each forging or each batch of forgings. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature, and the test procedure is to be in accordance with the requirements of Chapter 2. The results of all tests are to comply with the requirements of the National or proprietary specification.

7.7.3 Values for the estimated average stress to rupture in 100 000 hours are given in Table 5.7.4 and may be used for design purposes.

Table 5.7.4 Mechanical properties for design purposes: estimated average values for stress to rupture in 100 000 hours (units N/mm^2)

Temperature °C	Grades of steel		
	Carbon-manganese	1 Cr $^1/_2$ Mo	2$^1/_4$ Cr 1Mo
380	227	–	–
390	203	–	–
400	179	–	–
410	157	–	–
420	136	–	–
430	117	–	–
440	100	–	–
450	85	290	–
460	73	262	–
470	63	235	210
480	55	208	186
490	–	181	165
500	–	155	145
510	–	129	128
520	–	103	112
530	–	80	98
540	–	62	84
550	–	49	72
560	–	42	61
570	–	36	49
580	–	32	–
590	–	29	–

■ *Section 8*
Ferritic steel forgings for low temperature service

8.1 Scope

8.1.1 The requirements for carbon-manganese and nickel steels suitable for low temperature service are detailed in this Section. They are applicable to all forgings used for the construction of cargo tanks, storage tanks and process pressure vessels for liquefied gases and, where the design temperature is less than 0°C, to forgings for the piping systems.

8.1.2 The requirements are also applicable to forgings for other pressure vessels and pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

8.1.3 In all cases, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

8.1.4 In addition to the steels in this Section, the austenitic stainless steels detailed in Section 9 may also be used for low temperature applications.

8.2 Chemical composition

8.2.1 The chemical composition of ladle samples is, in general, to comply with the requirements given in Table 5.8.1.

8.3 Heat treatment

8.3.1 Forgings are to be normalised, normalised and tempered or quenched and tempered in accordance with the approved specification.

8.4 Mechanical tests

8.4.1 At least one tensile and three Charpy V-notch impact test specimens are to be taken from each forging or each batch of forgings. Where the dimensions and shape allow, the test specimens are to be cut in a longitudinal direction.

8.4.2 The impact tests are to be carried out at a temperature appropriate to the type of steel and for the proposed application. Where forgings are intended for ships for liquefied gases, the test temperature is to be in accordance with the requirements given in Table 3.6.3 in Chapter 3.

8.4.3 The results of all tensile tests are to comply with the approved specification.

8.4.4 The average energy values for impact tests are also to comply with the approved specification and generally with the requirements of Ch 3,6. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4 for re-test procedures.

Table 5.8.1 Chemical composition of ferritic steel forgings

Grade of steel	C %	Si %	Mn %	Ni %	P %	S %	Residual elements %	Grain refiners % Al	Grain refiners % Other
LT–AH (AH40) LT–DH (DH40) LT–EH (EH40)	0,18 max.	0,50 max.	0,90–1,60	0,40 max.	0,035 max.	0,030 max.	Cu 0,35 max. Cr 0,20 max. Mo 0,08 max. Total 0,60 max.	Total 0,020 min. Acid soluble 0,015 min.	(*See* Note) Nb 0,02 – 0,05 V 0,03 – 0,10 Ti 0,02 max.
LT–FH (FH40)	0,16 max.			0,80 max.	0,025 max.	0,025 max.			
$1^1/_2$Ni	0,18 max.	0,10 – 0,35	0,30–1,50	1,30–1,70		0,020 max.	Cu 0,35 max. Cr 0,25 max. Mo 0,08 max. Total 0,60 max.		
$3^1/_2$Ni	0,15 max.		0,30–0,90	3,20–3,80					
5Ni	0,12 max.			4,70–5,30					
9 Ni	0,10 max.			8,50–10,0					

NOTE
The steel is to contain aluminium, niobium, vanadium or other suitable grain refining elements, either singly or in any combination. When used singly, the steel is to contain the specified minimum content of the grain refining element. When used in combination, the specified minimum content of each element is not applicable.

8.5 Non-destructive examination

8.5.1 Non-destructive testing is to be carried out in accordance with the requirements of the approved forging drawing and specification, or as otherwise agreed between the manufacturer, purchaser and Surveyor.

8.6 Pressure tests

8.6.1 When applicable, pressure tests are to be carried out in accordance with the requirements of the relevant Rules.

■ *Section 9*
Austenitic stainless steel forgings

9.1 General

9.1.1 Forgings in austenitic stainless steels are acceptable for use in the construction of cargo tanks, storage tanks and piping systems for chemicals and liquefied gases. They may also be accepted for elevated temperature service in boilers.

9.1.2 Where it is proposed to use forgings in these types of steels, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval. These are to comply, in general, with the requirements of Ch 3,7 for austenitic steel plates.

9.1.3 Unless otherwise agreed, impact tests are not required for acceptance purposes. Where they are required, tests are to be made on longitudinal specimens at minus 196°C and the minimum average energy requirement is to be 41J.

9.2 Mechanical properties for design purposes

9.2.1 Where austenitic stainless steel forgings are intended for service at elevated temperatures, the nominal values for the minimum one per cent proof stress at temperatures of 100°C and higher given in Table 5.9.1 may be used for design purposes. Verification of these values is not required except for material complying with a National or proprietary specification in which the elevated temperature properties proposed for design purposes are higher than those given in Table 5.9.1.

9.3 Non-destructive examination

9.3.1 Non-destructive examination is to be carried out in accordance with the requirements of the approved forging drawing and specification or as otherwise agreed between the manufacturer, purchaser and Surveyor.

9.4 Intergranular corrosion tests

9.4.1 Where corrosive conditions are anticipated in service, intergranular corrosion tests are required on forgings in Grades 304, 316 and 317. Such tests may not be required for Grades 304L, 316L, 321 and 347.

Table 5.9.1 Mechanical properties for design purposes: austenitic stainless steels

Grade	Nominal 1% proof stress (N/mm^2) at a temperature of												
	100°C	150°C	200°C	250°C	300°C	350°C	400°C	450°C	500°C	550°C	600°C	650°C	700°C
304L	168	150	137	128	122	116	110	108	106	102	100	96	93
316L	177	161	149	139	133	127	123	119	115	112	110	107	105
316LN	238	208	192	180	172	166	161	157	152	149	144	142	138
321	192	180	172	164	158	152	148	144	140	138	135	130	124
347	204	192	182	172	166	162	159	157	155	153	151	—	—

9.4.2 When an intergranular corrosion test is specified, it is to be carried out in accordance with the procedure given in Ch 2,8.1.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for boiler tubes, superheater tubes and pipes intended for use in the construction of boilers, pressure vessels and pressure piping systems.

1.1.2 In addition to specifying mechanical properties for the purpose of acceptance testing, these requirements give details of appropriate mechanical properties at elevated temperatures to be used for design purposes.

1.1.3 Except for pipes for Class III pressure systems (as defined in the relevant Rules), all pipes and tubes are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2, the general requirements of this Section and the appropriate specific requirements given in Sections 2, 3, 4, 5 and 6.

1.1.4 Steels intended for the piping systems for liquefied gases where the design temperature is less than 0°C are to comply with the specific requirements of Section 4 or 5.

1.1.5 As an alternative to 1.1.3 and 1.1.4, pipes or tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.6 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

1.1.7 Pipes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of an acceptable National specification. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. Forge butt welded pipes are not acceptable for oil fuel systems, heating coils in oil tanks, primary refrigerant systems and other applications where the pressure exceeds 4,0 bar (4,1 kgf/cm^2).

1.2 Manufacture

1.2.1 Pipes for Class I and II pressure systems, boiler and superheater tubes are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR'). The steel used is to be manufactured and cast in ingot moulds or by an approved continuous casting process as detailed in Ch 3,1.3.

1.2.2 Unless a particular method is requested by the purchaser, pipes and tubes may be manufactured by any of the following methods:

- Hot finished seamless.
- Cold finished seamless.
- Electric resistance or induction welded.
- Cold finished electric resistance or induction welded.
- Electric fusion welded.

1.2.3 Care is to be taken during manufacture that the pipe or tube surfaces coming in contact with any non-ferrous metals or their compounds are not contaminated to such an extent as could prove harmful during subsequent fabrication and operation.

1.3 Quality

1.3.1 All pipes and tubes are to have a workmanlike finish and are to be clean and free from such surface and internal defects as can be established by the specified tests.

1.3.2 All pipes and tubes are to be reasonably straight. The ends are to be cut nominally square with the axis of the pipe or tube, and are to be free from excessive burrs.

1.4 Dimensional tolerances

1.4.1 The tolerances on the wall thickness and diameter of pipes and tubes are to be in accordance with an acceptable National specification.

1.5 Chemical composition

1.5.1 The requirements for the chemical composition of ladle samples and acceptable methods of deoxidation are detailed in subsequent Sections in this Chapter.

1.6 Heat treatment

1.6.1 All pipes and tubes are to be supplied in the condition detailed in the relevant specific requirements.

1.7 Test material

1.7.1 Pipes and tubes are to be presented for test in batches. The size of a batch and the number of tests to be performed are dependent on the application.

1.7.2 Where heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size, manufactured from the same types of steel and subjected to the same finishing treatment in a continuous furnace, or heat treated in the same furnace charge in a batch type furnace.

1.7.3 Where no heat treatment has been carried out, a batch is to consist of pipes or tubes of the same size manufactured by the same method from material of the same type of steel.

1.7.4 For pipes for Class I pressure systems and boiler and superheater tubes, at least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests at ambient temperature.

1.7.5 For pipes for Class II pressure systems, each batch is to contain not more than the number of lengths given in Table 6.1.1. Tests are to be carried out on at least one pipe selected at random from each batch or part thereof.

Table 6.1.1 Batch sizes for pipes for Class II pressure systems

Outside diameter mm	Number in batch
≤323,9	200 pipes as made
>323,9	100 pipes as made

1.8 Dimensions of test specimens and test procedures

1.8.1 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

1.9 Visual and non-destructive testing

1.9.1 All pipes for Class I and II pressure systems, boiler and superheater tubes, are to be presented for visual examination and verification of dimensions. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the pipes and tubes to be carried out.

1.9.2 For welded pipes and tubes, the manufacturer is to employ suitable non-destructive methods for the quality control of the welds. It is preferred that this examination is carried out on a continuous basis.

1.10 Hydraulic test

1.10.1 Each pipe and tube is to be subjected to a hydraulic test at the manufacturer's works.

1.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 140 bar (143 kgf/cm^2):

$$P = \frac{20st}{D} \left(P = \frac{200st}{D}\right)$$

where

P = test pressure, in bar (kgf/cm^2)
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 80 per cent of the specified minimum yield stress, in N/mm^2 (kgf/mm^2), for ferritic steels and 70 per cent of the specified minimum, 1,0 per cent proof stress, in N/mm^2 (kgf/mm^2), for austenitic steels. These relate to the values specified for acceptance testing at ambient temperature.

1.10.3 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted. Where it is proposed to adopt a test pressure other than that determined as in 1.10.2, the proposal will be subject to special consideration.

1.10.4 Subject to special approval, either an ultrasonic or eddy current test can be accepted in lieu of the hydraulic test.

1.11 Rectification of defects

1.11.1 Surface imperfections may be removed by grinding provided that the thickness of the pipe or tube after dressing is not less than the required minimum thickness. The dressed area is to be blended into the contour of the tube.

1.11.2 By agreement with the Surveyor, the repair of minor defects by welding can be accepted, subject to welding procedure tests which demonstrate acceptable properties appropriate for the grade of pipe to be repaired. Weld procedure tests are to be subjected to the same heat treatment as will be applied to the actual pipes after weld repair.

1.11.3 The repaired area is to be tested by magnetic particle examination, or, for austenitic steels, by liquid penetrant examination on completion of welding, heat treatment and surface grinding.

1.12 Identification

1.12.1 Pipes and tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Identification mark for the specification or grade of steel.
(d) Identification number and/or initials which will enable the full history of the item to be traced.
(e) The personal stamp of the Surveyor responsible for the final inspection.

1.12.2 It is recommended that hard stamping be restricted to the end face, but it may be accepted in other positions in accordance with National Standards and practices.

1.13 Certification of materials

1.13.1 Unless a LR certificate is specified in other parts of the Rules, a manufacturer's certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.13.2 The manufacturer is to provide LR with the following information:

(a) Purchaser's name and order number.
(b) If known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Specification or the grade of material.
(e) Description and dimensions.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples.
(h) Mechanical test results, and results of the intercrystalline corrosion tests where applicable.
(j) Condition of supply.

1.13.3 As a minimum, the chemical composition stated on the certificate is to include the content of all the elements detailed in the specific requirements. Where rimming steel is supplied, this is to be stated on the certificate.

1.13.4 When steel is not produced at the pipe or tube mill, a certificate is to be supplied by the steelmaker stating the process of manufacture, the cast number and the ladle analysis.

1.13.5 The steel manufacturer's works is to be approved by LR.

■ *Section 2* Seamless pressure pipes

2.1 Scope

2.1.1 Provision is made in this Section for seamless pressure pipes in carbon, carbon-manganese and low alloy steels.

2.1.2 Where pipes are used for the manufacture of pressure vessel shells and headers, the requirements for forgings in Ch 5,7 are applicable where the wall thickness exceeds 40 mm.

2.2 Manufacture and chemical composition

2.2.1 Pipes are to be manufactured by a seamless process and may be hot or cold finished.

2.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.2.1.

Table 6.2.1 Chemical composition of seamless pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %											
			C	Si	Mn	S max.	P max.	Residual elements						
								Ni	Cr	Mo	Cu	Sn	V	Al
Carbon and carbon-manganese	320	Semi-killed or killed	≤0,16	–	0,40–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.						
	360		≤0,17	≤0,35	0,40–0,80	0,045	0,045							
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045							
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045							
	490		≤0,23	≤0,35	0,80–1,50	0,045	0,045							
1Cr1/2Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30 max.	0,70–1,10	0,45 – 0,65	0,25 max.	0,03 max.	—	≤0,020
2 1/4Cr1Mo	410 490	Killed	0,08–0,15	0,10–0,50	0,40–0,70	0,040	0,040	0,30 max.	2,0–2,5	0,90–1,20	0,25 max.	0,03 max.	—	≤0,020
1/2Cr1/2Mo1/4V	460	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	0,30	0,30–0,60	0,50–0,70	0,25 max.	0,03 max.	0,22–0,32	≤0,020

2.3 Heat treatment

2.3.1 Pipes are to be supplied in the condition given in Table 6.2.3.

2.4 Mechanical tests

2.4.1 All pipes are to be presented in batches as defined in Section 1.

2.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

2.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.2.2.

2.5 Mechanical properties for design

2.5.1 Values for nominal minimum lower yield or 0,2 per cent proof stress at temperatures of 50°C and higher are given in Table 6.2.4 and are intended for design purposes only. Verification of these values is not required, except for materials complying with National or proprietary specification where the elevated temperature properties used for design are higher than those given in Table 6.2.4.

2.5.2 In such cases, at least one tensile test at the proposed design or other agreed temperature is to be made on each cast. The test specimen is to be taken from material adjacent to that used for tests at ambient temperature and tested in accordance with the procedures given in Chapter 2. If tubes or pipes of more than one thickness are supplied from one cast, the test is to be made on the thickest tube or pipe.

Table 6.2.3 Heat treatment

Type of steel		Condition of supply
Carbon and carbon-manganese		
Hot finished		Hot finished (*see* Note 1) Normalised (*see* Note 2)
Cold finished		Normalised (*see* Note 2)
Alloy steel		
1Cr1/2Mo		Normalised and tempered
21/4Cr1Mo	Grade 410	Fully annealed
	Grade 490	Normalised and tempered 650—780°C
	Grade 490	Normalised and tempered 650—750°C
1/2Cr1/2Mo1/4V		Normalised and tempered

NOTES
1. Provided that the finishing temperature is sufficiently high to soften the material.
2. Normalised and tempered at the option of the manufacturer.

2.5.3 As an alternative to 2.5.2, a manufacturer may carry out an agreed comprehensive test program for a stated grade of steel to demonstrate that the specified minimum mechanical properties at elevated temperatures can be consistently obtained. This test program is to be carried out under the supervision of the Surveyors, and the results submitted for assessment and approval. When a manufacturer is approved on this basis, tensile tests at elevated temperatures are not required for acceptance purposes, but at the discretion of the Surveyors occasional check tests of this type may be requested.

2.5.4 Values for the estimated average stress to rupture in 100 000 hours are given in Table 6.2.5 and may be used for design purposes.

Table 6.2.2 Mechanical properties for acceptance purposes: seamless pressure pipes (maximum wall thickness 40 mm), *see* 2.1.2

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant C	Bend test diameter of former (t = thickness)
Carbon and carbon-manganese	320	195	320—440	25	0,10	4t
	360	215	360—480	24	0,10	
	410	235	410—530	22	0,08	
	460	265	460—580	21	0,07	
	490	285	490—610	21	0,07	
1Cr1/2Mo	440	275	440—590	22	0,07	4t
21/4Cr1Mo	410 (*see* Note 1)	135	410—560	20	0,07	4t
	490 (*see* Note 2)	275	490—640	16		
1/2Cr1/2Mo1/4V	460	275	460—610	15	0,07	4t

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.4 Mechanical properties for design purposes: seamless pressure pipes

Type of steel	Grade	Nominal minimum lower yield or 0,2% proof stress N/mm²											
		Temperature °C											
		50	100	150	200	250	300	350	400	450	500	550	600
Carbon and carbon-manganese	320	172	168	158	147	125	100	91	88	87	—	—	—
	360	192	187	176	165	145	122	111	109	107	—	—	—
	410	217	210	199	188	170	149	137	134	132	—	—	—
	460	241	234	223	212	195	177	162	159	156	—	—	—
	490	256	249	237	226	210	193	177	174	171	—	—	—
1Cr$^1/_2$Mo	440	254	240	230	220	210	183	169	164	161	156	151	—
2$^1/_2$Cr1Mo	410 (*see* Note 1)	121	108	99	92	85	80	76	72	69	66	64	62
	490 (*see* Note 2)	268	261	253	245	236	230	224	218	205	189	167	145
$^1/_2$Cr$^1/_2$Mo$^1/_4$V	460	266	259	248	235	218	192	184	177	168	155	148	—

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Table 6.2.5 Mechanical properties for design purposes: seamless pressure pipes – Estimated values for stress to rupture in 100 000 hours (units N/mm²)

Temperature °C	Carbon and carbon-manganese		1Cr$^1/_2$Mo	2$^1/_4$Cr1Mo		$^1/_2$Cr$^1/_2$Mo$^1/_4$V
	Grade 320 360 410	Grade 460 490	Grade 440	Grade 410 Annealed	Grade 490 Normalised and tempered (*see* Note)	Grade 460
380	171	227	—	—	—	—
390	155	203	—	—	—	—
400	141	179	—	—	—	—
410	127	157	—	—	—	—
420	114	136	—	—	—	—
430	102	117	—	—	—	—
440	90	100	—	—	—	—
450	78	85	—	196	221	—
460	67	73	—	182	204	—
470	57	63	—	168	186	—
480	47	55	210	154	170	218
490	36	47	177	141	153	191
500	—	41	146	127	137	170
510	—	—	121	115	122	150
520	—	—	99	102	107	131
530	—	—	81	90	93	116
540	—	—	67	78	79	100
550	—	—	54	69	69	85
560	—	—	43	59	59	72
570	—	—	35	51	51	59
580	—	—	—	44	44	46

NOTE
When the tempering temperature exceeds 750°C, the values for Grade 410 are to be used.

■ *Section 3*
Welded pressure pipes

3.1 Scope

3.1.1 Provision is made in this Section for welded pressure pipes in carbon, carbon-manganese and low alloy steels.

3.2 Manufacture and chemical composition

3.2.1 Pipes are to be manufactured by the electric resistance or induction welding process and, if required, may be subsequently hot reduced or cold finished.

3.2.2 Where it is proposed to use other welding processes, details of the welding processes and procedures are to be submitted for review.

3.2.3 In all cases, welding procedure tests are required. Test samples are to be subjected to the same heat treatment as the pipe.

3.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.3.1.

3.3 Heat treatment

3.3.1 Pipes are to be supplied in the heat treated condition given in Table 6.3.3.

3.4 Mechanical tests

3.4.1 All pipes are to be presented in batches as defined in Section 1.

3.4.2 Each pressure pipe selected for test is to be subjected to tensile and flattening or bend tests.

3.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.3.2.

3.5 Mechanical properties for design

3.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460 and 1Cr½Mo steel can be taken from the appropriate Tables in Section 2.

Table 6.3.1 Chemical composition of welded pressure pipes

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle samples %					
			C	Si	Mn	S max.	P max.	Residual elements
Carbon and carbon-manganese	320	Any method (see Note)	≤0,16	—	0,30–0,70	0,050	0,050	Ni 0,30 max. Cr 0,25 max. Mo 0,10 max. Cu 0,30 max. Total 0,70 max.
	360		≤0,17	≤0,35	0,40–1,00	0,045	0,045	
	410	Killed	≤0,21	≤0,35	0,40–1,20	0,045	0,045	
	460		≤0,22	≤0,35	0,80–1,40	0,045	0,045	
1Cr½Mo	440	Killed	0,10–0,18	0,10–0,35	0,40–0,70	0,040	0,040	Ni 0,30 max. Cr 0,70–1,10 Mo 0,45–0,65 Cu 0,25 max. Sn 0,03 max. Al ≤0,020

NOTE
For rimming steels, the carbon content may be increased to 0,19% max.

Table 6.3.2 Mechanical properties for acceptance purposes: welded pressure pipes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*
Carbon and carbon-manganese	320	195	320 – 440	25	0,10
	360	215	360 – 480	24	0,10
	410	235	410 – 530	22	0,08
	460	265	460 – 580	21	0,07
$1Cr^1/_2Mo$	440	275	440 – 590	22	0,07

Table 6.3.3 Heat treatment: welded pressure pipes

Type of steel	Condition of supply
Carbon and carbon-manganese, *see* Note	Normalised (Normalised and tempered at the option of the manufacturer)
$1Cr^1/_2Mo$	Normalised and tempered

NOTE
Subject to special approval, electric resistance welded (ERW) pipes and tubes in grades 320 and 360 may be supplied without heat treatment for the following applications:
(a) Class 2 piping systems, except for liquefied gases or other low temperature applications.
(b) Class 3 piping systems.

■ *Section 4*
Ferritic steel pressure pipes for low temperature service

4.1 Scope

4.1.1 Provision is made in this Section for carbon, carbon-manganese and nickel pipes intended for use in the piping arrangements for liquefied gases where the design temperature is less than 0°C. These requirements are also applicable for other types of pressure piping systems where the use of steels with guaranteed impact properties at low temperatures is required.

4.2 Manufacture and chemical composition

4.2.1 Carbon and carbon-manganese steel pipes are to be manufactured by a seamless, electric resistance or induction welding process.

4.2.2 Nickel steel pipes are to be manufactured by a seamless process.

4.2.3 Seamless pipes may be hot finished or cold finished. Welded pipes may be as-welded, hot finished or cold finished. The terms ‘hot finished’, ‘cold finished’ and ‘as-welded’ apply to the condition of the pipes before final heat treatment.

4.2.4 The method of deoxidation and the chemical composition of ladle samples are to comply with the appropriate requirements given in Table 6.4.1.

4.3 Heat treatment

4.3.1 Pipes are to be supplied in the condition given in Table 6.4.3.

4.4 Mechanical tests

4.4.1 All pipes are to be presented for test in batches as defined in Section 1 for Class 1 pressure piping systems, but in addition the material in each batch is to be from the same cast.

4.4.2 At least two per cent of the number of lengths in each batch is to be selected at random for the preparation of tests.

4.4.3 Each pressure pipe selected for test is to be subjected to tensile, flattening or bend test at room temperature and, where the wall thickness is 6 mm or greater, an impact test at the test temperature specified in Table 6.4.2.

4.4.4 The impact tests are to consist of a set of three Charpy V-notch test specimens cut in the longitudinal direction with the notch perpendicular to the original surface of the pipe. The dimensions of the test specimens are to be in accordance with the requirements of Chapter 2.

4.4.5 The results of all tensile, flattening and bend tests are to comply with the appropriate values in Table 6.4.2.

4.4.6 The average value for impact test specimens is to comply with the appropriate requirements of Table 6.4.2. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value. *See* Ch 2,1.4.1 for re-test procedures.

Table 6.4.1 Chemical composition

Type of steel	Grade	Method of deoxidation	Chemical composition of ladle sample %							
			C max.	Si	Mn	P max.	S max.	Ni	Al_{sol} *see* Note	Residual elements
Carbon	360	Fully killed	0,17	0,10—0,35	0,40—1,00	0,030	0,025	—	0,015 min.	Cr 0,25 Cu 0,30 Mo 0,10 Ni 0,30 Total 0,70
Carbon-manganese	410 and 460		0,20	0,10—0,35	0,60—1,40	0,030	0,025	—	0,015 min.	
$3^{1}/_{2}$Ni	440		0,15	0,15—0,35	0,30—0,90	0,025	0,020	3,25—3,75	—	Cr 0,25 Cu 0,30 Mo 0,10 Total 0,60
9Ni	690		0,13	0,15—0,30	0,30—0,90	0,025	0,020	8,50—9,50	—	

NOTE
Where a minimum Al_{sol} of 0,015% is specified, the determination of the total aluminium is acceptable provided that the result is not less than 0,020%.

Table 6.4.2 Mechanical properties for acceptance purposes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Charpy V-notch impact tests	
							Test temperature °C	Average energy J minimum
Carbon	360	210	360—480	24	0,10	4*t*	–40	27
Carbon-manganese	410 460	235 260	410—530 460—580	22 21	0,08 0,07	4*t*	–50	27
$3^{1}/_{2}$Ni	440	245	440—590	16	0,08	4*t*	–95	34
9Ni	690	510	690—840	15	0,08	4*t*	–196	41

For standard subsidiary impact test specimens, the minimum energy values are to be as follows:

Required average energy value for standard 10 mm x 10 mm	Subsidiary 10 mm x 7,5 mm	Subsidiary 10 mm x 5 mm
	Average energy	Average energy
27 J 34 J 41 J	22 J 28 J 34 J	18 J 23 J 27 J

Table 6.4.3 Heat treatment

Type of steel	Condition of supply
Carbon and carbon-manganese	Hot finished Normalised Normalised and tempered
$3^{1}/_{2}$ Ni	Normalised Normalised and tempered
9Ni	Double normalised and tempered Quenched and tempered

Section 5
Austenitic stainless steel pressure pipes

5.1 Scope

5.1.1 Provision is made in this Section for austenitic stainless steel pipes suitable for use in the construction of the piping systems for chemicals and for liquefied gases where the design temperature is not less than minus 165°C and for bulk chemical tankers.

5.1.2 Austenitic stainless steels are also suitable for service at elevated temperatures. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

5.1.3 Where it is intended to supply seamless pipes in the direct quenched condition, a programme of tests for approval is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR, *see* Ch 1,2.2.

5.2 Manufacture and chemical composition

5.2.1 Pipes are to be manufactured by a seamless or a continuous automatic electric fusion welding process.

5.2.2 Welding is to be in a longitudinal direction, with or without the addition of filler metal.

5.2.3 The chemical composition of the ladle samples is to comply with the appropriate requirements of Table 6.5.1.

5.3 Heat treatment

5.3.1 Pipes are generally to be supplied by the manufacturer in the solution treated condition over their full length.

5.3.2 Alternatively, seamless pipes may be direct quenched immediately after hot forming, while the temperature of the pipes is not less than the specified minimum solution treatment temperature.

5.4 Mechanical tests

5.4.1 All pipes are to be presented in batches as defined in Section 1 for Class I and II piping systems.

5.4.2 Each pipe selected for test is to be subjected to tensile and flattening or bend tests.

5.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.5.2.

Table 6.5.1 Chemical composition

Type of steel	Grade	Chemical composition of ladle sample %								
		C max.	Si	Mn	P max.	S max.	Cr	Mo	Ni	Others
304L	490	0,03	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	—
316L	490	0,03	<1,00	<2,00	0,045	0,030	16,0 – 18,5	2,0–3,0	11,0 – 14,5	—
321	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Ti ≥5 x C ≤0,80
347	510	0,08	<1,00	<2,00	0,045	0,030	17,0 – 19,0	—	9,0 – 13,0	Nb ≥10 x C ≤1,00

Table 6.5.2 Mechanical properties for acceptance purposes

Type of steel	Grade	0,2% proof stress N/mm^2 (*see* Note)	1,0% proof stress N/mm^2	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)
304L	490	175	205	490 – 690	30	0,09	3*t*
316L	490	185	215	490 – 690	30	0,09	3*t*
321	510	195	235	510 – 710	30	0,09	3*t*
347	510	205	245	510 – 710	30	0,09	3*t*

NOTE
The 0,2% proof stress values given for information purposes and unless otherwise agreed are not required to be verified by test.

5.5 Intergranular corrosion tests

5.5.1 For materials used for piping systems for chemicals, intercrystalline corrosion tests are to be carried out on one per cent of the number of pipes in each batch, with a minimum of one pipe.

5.5.2 For pipes with an outside diameter not exceeding 40 mm, the test specimens are to consist of a full cross-section. For larger pipes, the test specimens are to be cut as circumferential strips of full wall thickness and having a width of not less than 12,5 mm. In both cases, the total surface area is to be between 15 and 35 cm^2.

5.5.3 Unless otherwise agreed or required for a particular chemical cargo, the testing procedure is to be in accordance with Ch 2,8.

5.5.4 After immersion, the full cross-section test specimens are to be subjected to a flattening test in accordance with the requirements of Chapter 2. The strip test specimens are to be subjected to a bend test through 90° over a mandrel of diameter equal to twice the thickness of the test specimen.

5.6 Fabricated pipework

5.6.1 Fabricated pipework is to be produced from material manufactured in accordance with 5.2, 5.3, 5.4 and 5.5.

5.6.2 Welding is to be carried out in accordance with an approved and qualified procedure by suitably qualified welders.

5.6.3 Fabricated pipework may be supplied in the as-welded condition without subsequent solution treatment provided that welding procedure tests have demonstrated satisfactory material properties including resistance to intercrystalline corrosion.

5.6.4 In addition, butt welds are to be subjected to 5 per cent radiographic examination for Class I, and 2 per cent for Class II pipes.

5.6.5 Fabricated pipework in the as-welded condition and intended for systems located on deck is to be protected by a suitable corrosion control coating.

5.7 Certification of materials

5.7.1 Each test certificate is to be of the type and give the information detailed in Ch 1,3.1 together with general details of heat treatment and, where applicable, the results obtained from intercrystalline corrosion tests. As a minimum, the chemical composition is to include the content of all the elements detailed in Table 6.5.1.

■ *Section 6*
Boiler and superheater tubes

6.1 Scope

6.1.1 Provision is made in this Section for boiler and superheater tubes in carbon, carbon-manganese and low alloy steels.

6.1.2 Austenitic stainless steels may also be used for this type of service. Where such applications are proposed, details of the chemical composition, heat treatment and mechanical properties are to be submitted for consideration and approval.

6.2 Manufacture and chemical composition

6.2.1 Tubes are to be seamless or welded and are to be manufactured in accordance with the requirements of Sections 2 and 3, respectively.

6.2.2 The method of deoxidation and the chemical composition of ladle samples are to comply with the requirements given in Table 6.2.1 or 6.3.1, as appropriate.

6.3 Heat treatment

6.3.1 All tubes are to be supplied in accordance with the requirements given in Table 6.2.3 or 6.3.3 as appropriate, except that 1Cr$^1/_2$Mo steel may be supplied in the normalised only condition when the carbon content does not exceed 0,15 per cent.

6.4 Mechanical tests

6.4.1 Tubes are to be presented for test in batches as defined in Section 1.

6.4.2 Each boiler and superheater tube selected for test is to be subjected to at least the following:
(a) Tensile test.
(b) Flattening or bending test.
(c) Expanding or flanging test.

6.4.3 The results of all mechanical tests are to comply with the appropriate requirements given in Table 6.6.1.

6.5 Mechanical properties for design

6.5.1 The mechanical properties at elevated temperature for carbon and carbon-manganese steels in Grades 320 to 460, 1Cr$^1/_2$Mo and 2$^1/_4$Cr1Mo steels can be taken from the appropriate Tables in Section 2.

6.5.2 Where rimming steel is used, the design temperature is limited to 400°C.

Table 6.6.1 Mechanical properties for acceptance purposes: boiler and superheater tubes

Type of steel	Grade	Yield stress N/mm^2	Tensile strength N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Flattening test constant *C*	Bend test diameter of former (*t* = thickness)	Drift expanding and flanging test minimum % increase in outside diameter		
							Ratio $\frac{\text{Inside diameter}}{\text{Outside diameter}}$		
							≤0,6	>0,6 ≤0,8	>0,8
Carbon and carbon-manganese	320 360 410 460	195 215 235 265	320–440 360–480 410–530 460–580	25 24 22 21	0,10 0,10 0,08 0,07	4*t*	12 12 10 8	15 15 12 10	19 19 17 15
1Cr$^1/_2$Mo	440	275	440–590	22	0,07	4*t*	8	10	15
2$^1/_2$Cr1Mo	410 (*see* Note 1) 490 (*see* Note 2)	135 275	410–560 490–640	20 16	0,07	4*t*	8	10	15

NOTES
1. Annealed condition.
2. Normalised and tempered condition.

Section

■ *Section 1* General requirements

1.1 Scope

1.1.1 This Section gives the general requirements for both grey (flake) and spheroidal (nodular) graphite iron castings intended for use in the construction of ships, other marine structures, machinery, boilers, pressure vessels and piping systems.

1.1.2 Where required by the relevant Rules dealing with design and construction, castings are to be manufactured and tested in accordance with Chapters 1 and 2, together with the requirements given in this Section and either Section 2 for grey iron castings or Section 3 for spheroidal graphite iron castings. Castings for crankshafts are additionally to comply with the requirements detailed in Section 4.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted, provided that these specifications give reasonable equivalence to the requirements of this Chapter or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.1.4 Where small castings are produced in large quantities, or where castings of the same type are produced in regular quantities, alternative survey procedures, in accordance with Ch 1,2.2, may be adopted subject to approval by Lloyd's Register (hereinafter referred to as 'LR').

1.2 Manufacture

1.2.1 Castings as designated in 1.1.2 are to be made at foundries approved by LR.

1.2.2 Suitable mechanical methods are to be employed for the removal of surplus material from castings. Thermal cutting processes are not acceptable, except as a preliminary operation to mechanical methods.

1.3 Quality of castings

1.3.1 Castings are to be free from surface or internal defects which would be prejudicial to their proper application in service. The surface finish is to be in accordance with good practice and any specific requirements of the approved plan.

1.4 Chemical composition

1.4.1 The chemical composition of the iron used is left to the discretion of the manufacturer, who is to ensure that it is suitable to obtain the mechanical properties specified for the castings.

1.5 Heat treatment

1.5.1 Except as required by 1.5.2, castings may be supplied in either the as cast or heat treated condition.

1.5.2 For some applications, such as elevated temperature service, or where dimensional stability is important, castings may require to be given a suitable tempering or stress relieving heat treatment. This is to be carried out after any refining heat treatment and before machining.

1.5.3 Where it is proposed to carry out local hardening of the surface of a casting, full details of the proposed procedure are to be submitted for approval.

1.6 Test material

1.6.1 At least one test sample is to be provided for each casting or batch of castings. For large castings, where more than one ladle of metal is used, one test sample is to be provided, from each ladle used.

1.6.2 A batch testing procedure may be adopted for castings with a fettled mass of 1 tonne or less. All castings in a batch are to be of similar type and dimensions, and cast from the same ladle of metal. One test sample is to be provided for each multiple of two tonnes of fettled castings in the batch.

1.6.3 Where separately cast test samples are used, they are to be cast in moulds made from the same type of material as used for the castings and are not to be stripped from the moulds until the temperature is below 500°C.

1.6.4 All test samples are to be suitably marked to identify them with the castings which they represent.

1.6.5 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent. For cast-on test samples, the sample is not to be separated from the casting until after heat treatment.

1.7 Mechanical tests

1.7.1 One tensile specimen is to be prepared from each test sample. The dimensions of the test specimens and the testing procedures used are to be in accordance with Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Section 2, 3 or 4, as appropriate.

1.7.3 In the case of castings supplied in the as cast condition which initially do not meet the requirements of 1.7.2, the manufacturer, by agreement with the purchaser, has the right to heat treat the castings, together with the representative test samples, and re-submit them for acceptance.

1.7.4 In the case of a batch of castings supplied in the heat treated condition which initially do not meet the requirements of 1.7.2, the manufacturer has the right to re-heat treat the batch together with the representative test samples, and re-submit the castings for acceptance. The number of reheat treatments and retestings will be restricted to two.

1.8 Visual and non-destructive examination

1.8.1 All castings are to be cleaned and adequately prepared for examination. The surfaces are not to be hammered, peened or treated in any way which may obscure defects.

1.8.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

1.8.3 All castings are to be presented to the Surveyor for visual examination and this is to include the examination of internal surfaces where applicable.

1.8.4 The non-destructive examination of castings is not required unless otherwise stated in the approved plan or where there is reason to suspect the soundness of the casting.

1.8.5 In the event of any casting proving defective during subsequent machining or testing it is to be rejected notwithstanding any previous certification.

1.9 Rectification of defective castings

1.9.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

1.9.2 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by vacuum impregnation with a suitable plastic filler, provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

1.9.3 Repairs by welding are not permitted on grey cast iron parts and generally not permitted for spheroidal or nodular graphite iron castings, but may be considered in special circumstances for spheroidal or nodular graphite iron castings. In such cases, full details of the proposed repair procedure are to be submitted for approval prior to the commencement of the proposed rectification.

1.10 Pressure testing

1.10.1 When required by the relevant Rules, castings are to be pressure tested before final acceptance. These tests are to be carried out in the presence and to the satisfaction of the Surveyor.

1.11 Identification of castings

1.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the castings when required.

1.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following particulars:

(a) Type and grade of cast iron.
(b) Identification number, cast number or other marking which will enable the full history of the casting to be traced.
(c) Manufacturer's name or trade mark.
(d) LR or Lloyd's Register and the abbreviated name of LR's local office.
(e) Personal stamp of Surveyor responsible for inspection.
(f) Test pressure, where applicable.
(g) Date of final inspection.

1.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

1.12.2 The manufacturer is to provide the Surveyor with a written statement giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and quality of cast iron.
(c) Identification number.
(d) General details of heat treatment, where applicable.
(e) Results of mechanical tests.
(f) Test pressure, where applicable.
(g) When specially required, the chemical analysis of ladle samples.

1.12.3 Where applicable, the manufacturer is to provide a signed statement regarding non-destructive testing as required by 1.8, together with a statement and/or a sketch detailing the extent and position of all weld repairs made to each casting as required by 1.9.

Section 2
Grey iron castings

2.1 Scope

2.1.1 This Section gives the specific requirements for grey cast iron castings.

2.2 Test material

2.2.1 Separately cast test samples in the form of cylindrical bars, 30 mm diameter and of a suitable length, are to be used unless otherwise agreed by LR. Test samples of other dimensions may be specially required for some components as may cast-on samples. In these circumstances, the tensile strength requirements are to be agreed.

2.2.2 When two or more test samples are cast simultaneously in a single mould, the bars are to be at least 50 mm apart.

2.2.3 Test samples may be cast integrally when a casting is both more than 20 mm thick and its mass exceeds 200 kg, subject to agreement between the manufacturer and the purchaser. The type and location of the samples are to be such as to provide approximately the same cooling conditions as for the casting it represents and are also subject to agreement.

2.2.4 For continuous melting of the same grade of cast iron in large tonnages the mass of a batch may be taken as the output of two hours of pouring.

2.2.5 Where 2.2.4 applies and production is carefully monitored by systematic checking of the melting process by, for example, chill testing, chemical analysis or thermal analysis, test samples may be taken at longer intervals as agreed by the Surveyor.

2.3 Mechanical tests

2.3.1 Only the tensile strength is to be determined, and the results obtained from tests are to comply with the minimum value specified for the castings being supplied. Except for crankshaft castings (*see* Section 4), the specified tensile strength is to be not less than 200 N/mm^2 subject to any additional requirements of the relevant Rules. The fractured surfaces of all tensile test specimens are to be granular and entirely grey in appearance.

Section 3
Spheroidal or nodular graphite iron castings

3.1 Scope

3.1.1 This Section gives the specific requirements for spheroidal or nodular graphite iron castings.

3.1.2 These requirements are generally applicable to castings intended for use at ambient temperatures. Additional requirements will be necessary when the castings are intended for service at either low or elevated temperatures. Impact test requirements are given for low temperature service in 3.4.2.

3.2 Heat treatment

3.2.1 The special qualities with 350 N/mm^2 and 400 N/mm^2 nominal tensile strength and impact test are to undergo a ferritising heat treatment, *see* 3.4.2.

3.3 Test material

3.3.1 The test samples are to be as detailed in Figs. 7.3.1, 7.3.2 or 7.3.3 The dimensions of the test specimens and testing procedures used are to be in accordance with Chapter 2. Test samples of other dimensions may be specially required for some castings and these are to be agreed with the Surveyor.

3.3.2 The test samples may be either gated to the casting or separately cast.

3.3.3 Where separately cast test samples are used, they are to be taken towards the end of pouring of the castings.

3.4 Mechanical tests

3.4.1 The tensile strength and elongation are to be determined and are to comply with the requirements of Table 7.3.1. Minimum values for the 0,2 per cent proof stress are also included in this Table but are to be determined only if included in the specification. Typical ranges of hardness values are also given in Table 7.3.1 and are intended for information purposes.

3.4.2 Impact tests may be required for some applications in which case the selection of the grade is to be confined to those listed in Table 7.3.2. These castings are to be given a ferritising heat treatment. The mechanical test results are to comply with Table 7.3.2.

3.4.3 Castings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 7.3.1 and 7.3.2 but subject to any additional requirements of the relevant Rules.

3.5 Metallographic examination

3.5.1 Samples for metallographic examination are to be prepared for spheroidal or nodular graphite iron castings. These samples are to be representative of each ladle used and may conveniently be taken from the tensile test specimens. Alternative arrangements for the provision of these samples may, however, be adopted subject to the concurrence of the Surveyor. They are, however, to be taken towards the end of the pour.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 100	12 40 30 80	50 90 60 150	75 125 65 165
Z *Rs*	To suit testing machine Approximately 5			

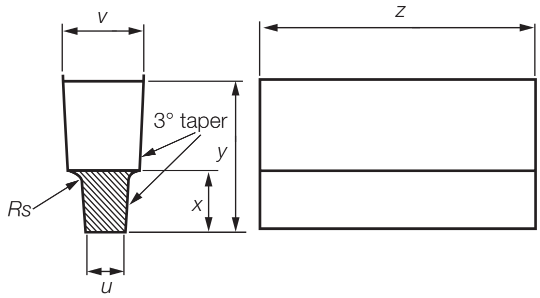


Fig. 7.3.1 Type A (U-type) test samples

Dimension	Standard sample, mm
u *v* *x* *y*	25 90 40 100
Z *Rs*	To suit testing machine Approximately 5

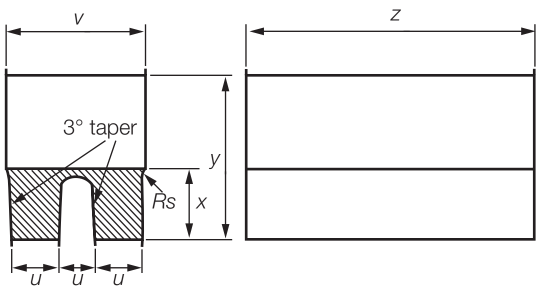


Fig. 7.3.2 Type B (Double U-type) test samples

3.5.2 Examination of the samples is to show that at least 90 per cent of the graphite is in a dispersed spheroidal or nodular form. Details of typical matrix structures are given in Table 7.3.1 and are intended for information purposes.

Dimension	Standard sample, mm	Alternative samples when specially required, mm		
u *v* *x* *y*	25 55 40 140	12 40 25 135	50 100 50 150	75 125 65 175
Z	To suit testing machine			
Minimum thickness of mould surrounding test sample	40	40	80	80

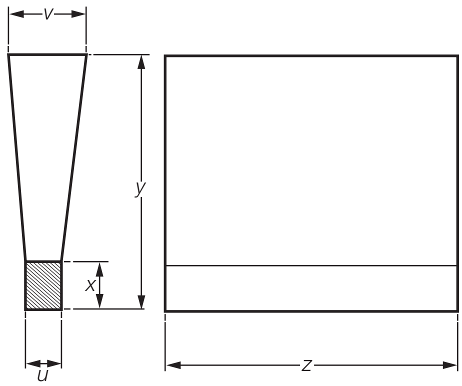


Fig. 7.3.3 Type C (Y-type) test samples

Table 7.3.1 Mechanical properties for acceptance purposes: spheroidal or nodular graphite iron castings

Specified minimum tensile strength N/mm^2	0,2% proof stress (*see* Note) N/mm^2 minimum	Elongation on 5,65 $\sqrt{S_o}$ % minimum	Typical hardness value HB (*see* 3.4.1)	Typical structure of matrix (*see* 3.5.1)
370	230	17	120 – 180	Ferrite
400	250	12	140 – 200	Ferrite
500	320	7	170 – 240	Ferrite/pearlite
600	370	3	190 – 270	Pearlite/ferrite
700	420	2	230 – 300	Pearlite
800	480	2	250 – 350	Pearlite or tempered structure

NOTE
Proof stresses need only be determined if specifically requested.

Table 7.3.2 Mechanical properties: special qualities

Specified minimum tensile strength N/mm^2	0,2% proof stress minimum (*see* Note 1) N/mm^2	Elongation on 5,65 $\sqrt{S_o}$ minimum % (*see* Note 2)	Typical hardness value	Charpy V-notch impact tests	
				Test temperature °C (*see* Note 3)	Average energy J minimum (*see* Note 4)
350	220	22	110 – 170	20 –40	17 (14) 12 (10)
400	250	18	140 – 200	20 –20	14 (11) 12 (10)

NOTES
1. Proof stresses need only be determined if specifically requested.
2. In the case of integrally cast samples, the acceptable elongation may be taken as 2 percentage points less.
3. Tests need only be made at either of the temperatures listed, as appropriate.
4. The average value measured on three Charpy V-notch specimens. One of the three values may be below the specified minimum average value, but not less than the value shown in brackets.
5. Typical structure of the matrix is ferrite.

Section 4
Iron castings for crankshafts

4.1 Scope

4.1.1 This Section gives additional requirements for cast iron crankshafts intended for diesel engines and compressors. For both of these applications, details of the proposed specification are to be submitted for approval.

4.1.2 Crankshaft castings in grey iron are acceptable only for compressors, and the specified minimum tensile strength is to be not less than 300 N/mm^2.

4.1.3 For crankshaft castings in spheroidal or nodular graphite iron, the specified minimum tensile strength is to be not less than 370 N/mm^2.

4.2 Manufacture

4.2.1 Details of the method of manufacture, including the arrangements proposed for the provision of test material, are to be submitted for approval.

4.2.2 Tests to demonstrate the soundness of prototype castings and the mechanical properties at important locations will be required.

4.3 Heat treatment

4.3.1 In general, crankshaft castings other than those which are fully annealed, normalised or oil quenched and tempered, are to receive a suitable stress relief heat treatment before machining.

4.3.2 Where it is proposed to harden the surfaces of machined pins and/or journals of cast iron crankshafts, details of the process are to be submitted for approval. Before such a process is applied to a crankshaft it is to be demonstrated by procedure tests, and to the satisfaction of the Surveyor, that the process is suitably controlled and does not impair the strength or soundness of the material.

4.4 Test material

4.4.1 Unless otherwise approved, the dimensions of the test samples are to be such as to ensure that they have mechanical properties representative of those of the average section of the crankshaft casting.

4.4.2 For large crankshaft castings, the test samples are to be cast integral with, or gated from, each casting.

4.4.3 The batch testing procedure detailed in 1.6.2 may be adopted only where small and identical crankshaft castings are produced in quantity. Generally, the fettled mass of each casting in a batch is not to exceed 100 kg, and in addition to tensile tests, the hardness of each casting is to be determined. For this purpose, a small flat is to be ground on each crankshaft, and Brinell hardness tests are to be carried out. The results obtained from these tests are to comply with the approved specification.

4.5 Non-destructive examination

4.5.1 Cast crankshafts are to be subjected to a full magnetic particle or dye penetrant examination after final machining and completion of any surface hardening operations.

4.5.2 Particular attention is to be given to the testing of the pins, journals and associated fillet radii.

4.5.3 Cracks and crack-like defects are not acceptable. Fillet radii are to be free from any indications.

4.6 Rectification of defective castings

4.6.1 Cast iron crankshafts are not to be repaired by welding, and blemishes are not to be plugged with a filler.

4.7 Certification of materials

4.7.1 The chemical composition of ladle samples is to be given in addition to the other particulars detailed in 1.12.2.

Section

Section 1
Plates, bars and sections

1.1 Scope

1.1.1 This Section makes provision for aluminium alloy plates, bars and sections intended for use in the construction of ships and other marine structures and for cryogenic applications.

1.1.2 Except as provided in 1.1.4, all items are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and those detailed in this Section.

1.1.3 The thickness of plates, sections and bars described by these requirements will be in the range between 3 and 50 mm. Plates and sections less than 3,0 mm thick may be manufactured and tested in accordance with the requirements of an acceptable national specification.

1.1.4 Plates less than 3,0 mm thick and sections less than 40 mm x 40 mm x 3,0 mm may be manufactured and tested in accordance with the requirements of an acceptable National specification.

1.1.5 Where the section thickness exceeds 50 mm, the requirements will be subject to special consideration.

1.1.6 Materials intended for the construction of cargo tanks or storage for liquefied gases, and for other low temperature applications, are to be manufactured in the 5083 alloy in the annealed condition.

1.1.7 As an alternative to 1.1.2 and 1.1.4, materials which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section and are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 Aluminium alloys are to be manufactured at works approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The alloys may be cast either in ingot moulds or by an approved continuous casting process. Plates are to be formed by rolling and may be hot or cold finished. Bars and sections may be formed by extrusion, rolling or drawing.

1.2.3 All melts are to be suitably degassed prior to casting such that the aim hydrogen content is less than 0,2 ml per 100 g.

1.3 Quality of materials

1.3.1 Materials are to be free from surface or internal defects of such a nature as would be harmful in service.

1.3.2 The manufacturer is to verify the integrity of pressure welds of closed extrusion profiles in accordance with 1.10.

Table 8.1.1 Underthickness tolerances for rolled products for marine construction

Nominal thickness range, mm	Underthickness tolerance for nominal width range, mm		
	≤1500	>1500 ≤2000	>2000 ≤3500
≥3,0 <4,0	0,10	0,15	0,15
≥4,0 <8,0	0,20	0,20	0,25
≥8,0 <12	0,25	0,25	0,25
≥12 <20	0,35	0,40	0,50
≥20 <50	0,45	0,50	0,65

1.4 Dimensional tolerances

1.4.1 Underthickness tolerances for rolled products for marine construction are given in Table 8.1.1.

1.4.2 Underthickness tolerances for extruded products are to comply with an acceptable National or International Standard.

1.4.3 There are to be no underthickness tolerances for materials for application in cryogenic process pressure vessels.

1.4.4 Dimensional tolerances other than permitted underthicknesses are to comply with an acceptable National or International Standard.

1.4.5 Verification of dimensions is the responsibility of the manufacturer. Acceptance by Surveyors of material which is later found to be defective does not absolve the manufacturer from this responsibility.

Table 8.1.2 Chemical composition, percentage

Element	5083	5383	5059	5086	5754	5456	6005–A (*see* Note 1)	6061 (*see* Note 1)	6082
Copper	0,10 max.	0,20 max.	0,25 max.	0,10 max.	0,10 max.	0,10 max.	0,30 max.	0,15—0,40	0,10 max.
Magnesium	4,0—4,9	4,0—5,2	5,0—6,0	3,5—4,5	2,6—3,6	4,7—5,5	0,40—0,70	0,80—1,20	0,60—1,20
Silicon	0,40 max.	0,25 max.	0,45 max.	0,40 max.	0,40 max.	0,25 max.	0,50—0,90	0,40—0,80	0,70—1,30
Iron	0,40 max.	0,25 max.	0,50 max.	0,50 max.	0,40 max.	0,40 max.	0,35 max.	0,70 max.	0,50 max.
Manganese	0,40—1,00	0,7—1,0	0,6—1,2	0,20—0,70	0,50 max. (*see* Note 2)	0,50—1,00	0,50 max. (*see* Note 3)	0,15 max.	0,40—1,00
Zinc	0,25 max.	0,40 max.	0,40—0,90	0,25 max.	0,20 max.	0,25 max.	0,20 max.	0,25 max.	0,20 max.
Chromium	0,05—0,25	0,25 max	0,25 max.	0,05—0,25	0,30 max. (*see* Note 2)	0,05—0,20	0,30 max. (*see* Note 3)	0,04—0,35	0,25 max.
Titanium	0,15 max.	0,15 max.	0,20 max.	0,15 max.	0,15 max.	0,20 max.	0,10 max.	0,15 max.	0,10 max.
Zirconium		0,20 max.	0,05—0,25						
Other elements: each	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.	0,15 max.

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. Mn + Cr = 0,10 min., 0,60 max.
3. Mn + Cr = 0,12 min., 0,50 max.

1.5 Chemical composition

1.5.1 Samples for chemical analysis are to be taken representative of each cast, or the equivalent where a continuous melting process is involved.

1.5.2 The chemical composition of these samples is to comply with the requirements of Table 8.1.2.

1.6 Heat treatment

1.6.1 The Aluminium 5000 series alloys, capable of being strain hardened, are to be supplied in any of the following temper conditions:

- O annealed
- H111 annealed with slight strain hardening
- H112 strain hardened from working at elevated temperatures
- H116 strain hardened and with specified resistance to exfoliation corrosion for alloys where the magnesium content is 4 per cent or more
- H321 strain hardened and stabilised.

1.6.2 The H116 temper is specially developed for use in a marine environment.

1.6.3 The Aluminium 6000 series alloys, capable of being age hardened, are to be supplied in either of the following temper conditions:

- T5 hot worked and artificially aged
- T6 solution treated and artificially aged.

1.7 Test material

1.7.1 Materials of the same product form, (i.e., plates, sections or bars) and thickness and from a single cast or equivalent, are to be presented for test in batches of not more than 2 tonnes, with the exceptions of those given in 1.7.2, 1.7.3 and 1.7.4.

1.7.2 For single plates or coils weighing more than 2 tonnes, only one tensile specimen per plate or coil is to be taken.

1.7.3 A tensile test specimen is required from each plate to be used in the construction of cargo tanks, secondary barriers and process pressure vessels with design temperatures below –55°C.

1.7.4 Extrusions, bars and sections of less than 1 kg/m in nominal weight are to be tested in batches of 1 tonne. Where the nominal weight is greater than 5 kg/m, one tensile test is to be carried out for every three tonnes produced, or fractions thereof.

1.7.5 If the material is supplied in the heat treated condition, each batch is to be treated in the same furnace charge or subjected to the same finishing treatment when a continuous furnace is used.

1.7.6 For plates over 300 mm in width, tensile test specimens are to be cut with their length transverse to the principal direction of rolling. For narrow plates and for sections and bars, the test specimens are to be cut in the longitudinal direction. Longitudinal tensile test specimens are accepted for the strain hardenable 5000 series alloys.

Table 8.1.3 Minimum mechanical properties for acceptance purposes of selected rolled aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on $5,65\sqrt{S_o}$ 4d, %	Elongation on $5,65\sqrt{S_o}$ 5d,%
5083-O	$3 \le t \le 50$ (*see* Note 3)	125	275–350	16	14
5083-H111	$3 \le t \le 50$	125	275–350	16	14
5083-H112	$3 \le t \le 50$	125	275	12	10
5083-H116	$3 \le t \le 50$	215	305	10 (*see* Note 1)	10
5083-H321	$3 \le t \le 50$	215–295	305–380	12	10
5086-O	$3 \le t \le 50$	100	240–305	16	14
5086-H111	$3 \le t \le 50$	100	240–305	16	14
5086-H112	$3 \le t \le 12,5$ $12,5 < t \le 50$	125 105	250 240	8 —	— 9
5086-H116	$3 \le t \le 50$	195	275	10 (*see* Note 2)	9
5059-O	$3 \le t \le 50$	160	330	24	24
5059-H111	$3 \le t \le 50$	160	330	24	24
5059-H116	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5059-H321	$3 \le t \le 20$ $20 < t \le 50$	270 260	370 360	10 10	10 10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H116	$3 \le t \le 50$	220	305	10	10
5383-H321	$3 \le t \le 50$	220	305	10	10
5456-O	$3 \le t \le 6,3$ $6,3 \le t \le 50$	130–205 125–205	290–365 285–360	16 16	— 14
5456-H116	$3 \le t \le 30$ $30 < t \le 40$ $40 < t \le 50$	230 215 200	315 305 285	10 — —	10 10 10
5456-H321	$3 \le t \le 12,5$ $12,5 \le t \le 40$ $40 \le t \le 50$	230–315 215–305 200–295	315–405 305–385 285–370	12 — —	— 10 10
5754-O	$3 \le t \le 50$	80	190–240	18	17

NOTES
1. 10% for thickness up to and including 12,5 mm.
2. 8% for thickness up to and including 6,3 mm.
3. For application to liquefied natural gas carriers or liquefied natural gas tankers where thicknesses are in excess of 50 mm, the mechanical properties given in this table are, in general, to be complied with.

Table 8.1.4 Minimum mechanical properties for acceptance purposes of selected extruded aluminium alloy products

Alloy and temper condition	Thickness, t, mm	0,2% proof stress R_p, N/mm^2	Tensile strength R_m N/mm^2	Elongation on $5{,}65\sqrt{S_o}$ 4d, %	Elongation on $5{,}65\sqrt{S_o}$ 5d,%
5083-O	$3 \le t \le 50$	110	270–350	14	12
5083-H111	$3 \le t \le 50$	165	275	12	10
5083-H112	$3 \le t \le 50$	110	270	12	10
5086-O	$3 \le t \le 50$	95	240–315	14	12
5086-H111	$3 \le t \le 50$	145	250	12	10
5086-H112	$3 \le t \le 50$	95	240	12	10
5059-H112	$3 \le t \le 50$	200	330	10	10
5383-O	$3 \le t \le 50$	145	290	17	17
5383-H111	$3 \le t \le 50$	145	290	17	17
5383-H112	$3 \le t \le 50$	190	310	13	13
6005A-T5	$3 \le t \le 50$	215	260	9	8
6005A-T6	$3 \le t \le 10$ $10 < t \le 50$	215 200	260 250	8 8	6 6
6061-T6	$3 \le t \le 50$	240	260	10	8
6082-T5	$3 \le t \le 50$	230	270	8	6
6082-T6	$3 \le t \le 5$ $5 < t \le 50$	250 260	290 310	6 10	— 8
NOTE The values are applicable for longitudinal and transverse tensile test specimens as well.					

1.7.7 Longitudinal tensile test specimens from a plate are to be taken at 1/3 width from the longitudinal edge. Longitudinal tensile test specimens taken from extruded sections should be taken in the range from 1/3 to 1/2 of the distance from the edge to the centre of the thickest region of the section.

1.8 Mechanical tests

1.8.1 At least one tensile test specimen is to be prepared from each batch of material submitted for acceptance.

1.8.2 Tensile test specimens are to be machined to the dimensions given in Fig. 2.2.3 in Chapter 2. Alternatively, machined proportional test specimens of circular cross-section in accordance with Fig. 2.2.2 in Chapter 2 may be used provided that the diameter is not less than 10 mm. Round bars may be tested in full section, or test specimens may be machined in accordance with the dimensions given in Fig. 2.2.2 in Chapter 2.

1.8.3 The results of all tensile tests are to comply with the values given in Tables 8.1.3 and 8.1.4, as applicable.

1.9 Corrosion tests

1.9.1 Rolled 5000 series alloys of type 5083, 5383, 5059, 5456 and 5086 in the H116 and H321 tempers intended for use in marine hull construction or in marine applications with frequent direct contact with seawater are to be corrosion tested with respect to exfoliation and intergranular corrosion resistance.

1.9.2 The manufacturer is to establish the relationship between microstructure and resistance to corrosion when the above alloys are approved. A reference photomicrograph taken at 500x, is to be prepared for each of the alloy-tempers and thickness ranges relevant. The reference photographs are to be taken from samples which have exhibited no evidence of exfoliation corrosion and a pitting rating of PB or better, when subjected to the test described in ASTM G66 (ASSET).The samples are also to have exhibited resistance to intergranular corrosion at a mass loss no greater than 15 mg/cm^2, when subjected to the test described in ASTM G67. Upon satisfactory establishment of the relationship between microstructure and resistance to corrosion, the master photomicrographs and the results of the corrosion tests are to be approved by LR. Production

practices are not to be changed after approval of the reference micrographs.

1.9.3 For batch acceptance of 5000 series alloys in the H116 and H321 tempers, metallographic examination of one sample selected from mid width at one end of a coil or random sheet or plate is to be carried out. The micro-structure of the sample is to be compared to the reference photomicrograph of acceptable material in the presence of the Surveyor. A longitudinal section perpendicular to the rolled surface is to be prepared for metallographic examination. If the microstructure shows evidence of continuous grain boundary network of aluminium-magnesium precipitate in excess of the reference photomicrographs of acceptable material, the batch is either to be rejected or tested for exfoliation corrosion resistance and intergranular corrosion resistance subject to the agreement of the Surveyor. The corrosion tests are to be in accordance with ASTM G66 and G67 or equivalent standards. If the results from testing satisfy the acceptance criteria stated in 1.9.2 the batch is accepted, otherwise it is to be rejected.

1.9.4 As an alternative to metallographic examination, each batch may be tested for exfoliation corrosion resistance and intergranular corrosion resistance, in accordance with ASTM G66 and G67 or equivalent standards.

1.9.5 Tempers that are corrosion tested in accordance with 1.9.3 are to be marked ‘M’ after the temper condition, e.g., 5083 H321 M.

1.10 Pressure weld tests

1.10.1 The integrity of pressure welds of closed profile extrusions is to be verified by examination of macrosections or drift expansion tests.

1.10.2 Every closed profile extrusion is to be sampled, except where the closed profile extrusions are equal to or shorter than 6,0 m long, in which case a batch is to comprise five profiles. Every sample is to be tested at both ends after final heat treatment.

1.10.3 Where verification is by examination of macro-sections, no indication of lack of fusion is permitted.

1.10.4 Where verification of fusion at pressure welds of closed profile extrusions is by drift expansion test, testing is to be generally in accordance with Ch 2,4.3. The minimum included angle of the mandrel is to be 60°, and the minimum specimen length, 50 mm. For acceptance, there is to be no failure by a clean split along the weld line.

1.11 Visual and non-destructive examination

1.11.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer, and acceptance by the Surveyors of material later found to be defective shall not absolve the manufacturer from this responsibility.

1.11.2 In general, the non-destructive examination of materials is not required for acceptance purposes. Manufacturers are expected, however, to employ suitable methods of non-destructive examination for the general maintenance of quality standards.

1.11.3 For applications where the non-destructive examination of materials is considered to be necessary, the extent of this examination, together with appropriate acceptance standards, are to be agreed between the purchaser, manufacturer and Surveyor.

1.12 Rectification of defects

1.12.1 Slight surface imperfections may be removed by mechanical means, provided that the prior agreement of the Surveyor is obtained, that the work is carried out to his satisfaction and that the final dimensions are acceptable. The repair of defects by welding is not allowed.

1.13 Identification

1.13.1 The manufacturer is to adopt a system of identification which will ensure that all finished material in a batch presented for test is of the same nominal chemical composition.

1.13.2 Products are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) Manufacturer’s name or trade mark.
(b) Alloy grade and temper condition.
(c) Identification mark which will enable the full history of the item to be traced.
(d) The stamp of the LR brand, .

1.14 Certification of materials

1.14.1 A manufacturer’s certificate validated by LR is to be issued, *see* Ch 1,3.1.

1.14.2 Each test certificate is to include the following particulars:

(a) Purchaser’s name and order number.
(b) Contract number.
(c) Address to which material is to be despatched.
(d) Description and dimensions.
(e) Alloy grade and temper condition.
(f) Identification mark which will enable the full history of the item to be traced.
(g) Chemical composition.
(h) Mechanical test results (not required on shipping statement).
(j) Details of temper condition and heat treatment, where applicable.

1.14.3 Where the alloy is not produced at the works at which it is wrought, a certificate is to be supplied by the manufacturer of the alloy stating the cast number and chemical composition. The works at which the alloy was produced must be approved by LR.

Section 2
Aluminium alloy rivets

2.1 Scope

2.1.1 Provision is made in this Section for aluminium alloy rivets intended for use in the construction of marine structures.

2.1.2 They are to be manufactured and tested in accordance with the appropriate requirements of Section 1 and those detailed in this Section.

2.2 Chemical composition

2.2.1 The chemical composition of bars used for the manufacture of rivets is to comply with the requirements of Table 8.2.1.

Table 8.2.1 Chemical composition, percentage

Element	5154A	6082
Copper	0,10 max.	0,10 max.
Magnesium	3,1 – 3,9	0,6 – 1,2
Silicon	0,50 max.	0,7 – 1,3
Iron	0,50 max.	0,50 max.
Manganese	0,1 – 0,5	0,4 – 1,0
Zinc	0,20 max.	0,20 max.
Chromium	0,25 max.	0,25 max.
Titanium	0,20 max.	0,10 max.
Other elements: each	0,05 max.	0,05 max.
total	0,15 max.	0,15 max.
Aluminium	Remainder	Remainder

2.3 Heat treatment

2.3.1 Rivets are to be supplied in the following condition:
5154A – annealed
6082 – solution treated.

2.4 Test material

2.4.1 Bars intended for the manufacture of rivets are to be presented for test in batches of not more than 250 kg. The material in each batch is to be the same diameter and nominal chemical composition.

2.4.2 At least one test sample is to be selected from each batch and, prior to testing, is to be heat treated in full cross-section and in a manner simulating the heat treatment applied to the finished rivets.

2.5 Mechanical tests

2.5.1 At least one tensile and one dump test specimen are to be prepared from each test sample.

2.5.2 The tensile test specimen may be either a suitable length of bar tested in full cross-section or a specimen machined to the dimensions given in Fig. 2.2.2 in Chapter 2.

2.5.3 The dump test specimen is to consist of a section cut from the bar with the ends perpendicular to the axis. The length of this section is to be equal to the diameter of the bar.

2.5.4 The results of tensile tests are to comply with the appropriate requirements of Table 8.2.2.

Table 8.2.2 Mechanical properties for acceptance purposes

Mechanical properties	5154A	6082
0,2% proof stress N/mm^2 min.	90	120
Tensile strength N/mm^2 min.	220	190
Elongation on 5,65$\sqrt{S_o}$ % min.	18	16

2.5.5 The dump test is to be carried out at ambient temperature and is to consist of compressing the specimen until the diameter is increased to 1,6 times the original diameter. After compression, the specimen is to be free from cracks.

2.6 Tests from manufactured rivets

2.6.1 At least three samples are to be selected from each consignment of manufactured rivets. Dump tests as detailed in 2.5 are to be carried out on each sample.

2.7 Identification

2.7.1 Each package of manufactured rivets is to be identified with attached labels giving the following details:
(a) Manufacturer's name or trade mark.
(b) Alloy grade.
(c) Rivet size.

2.8 Certification of materials

2.8.1 A manufacturer's certificate is to be issued (*see* Ch 1,3.1) and for each consignment of manufactured rivets is to include the following particulars:
(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Specification.

Section 3
Aluminium alloy castings

3.1 Scope

3.1.1 Provision is made in this Section for aluminium alloy castings intended for use in the construction of ships, ships for liquid chemicals and other marine structures and liquefied gas piping systems where the design temperature is not lower than minus 165°C. These materials should not be used for piping systems outside cargo tanks except for short lengths of pipes attached to the cargo tanks in which case fire-resisting insulation should be provided.

3.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2 and also with the requirements of this Section.

3.1.3 As an alternative to 3.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.2 Manufacture

3.2.1 Castings are to be manufactured at foundries approved by LR.

3.3 Quality of castings

3.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

3.4 Chemical composition

3.4.1 The chemical composition of a sample from each cast is to comply with the requirements given in Table 8.3.1. Suitable grain refining elements may be used at the discretion of the manufacturer. The content of such elements is to be reported in the ladle analysis.

3.4.2 Where it is proposed to use alloys not specified in Table 8.3.1, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.4.3 When a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor.

Table 8.3.1 Chemical composition, percentage

Alloy / Element		Al–Mg 3	Al–Si 12	Al–Si 10 Mg	Al–Si 7 High purity
Copper		0,1 max.	0,1 max.	0,1 max.	0,1 max.
Magnesium		2,5—4,5	0,1 max.	0,15—0,4	0,25—0,45
Silicon		0,5 max.	11,0—13,5	9,0—11,0	6,5—7,5
Iron		0,5 max.	0,7 max.	0,6 max.	0,2 max.
Manganese		0,6 max.	0,5 max.	0,6 max.	0,1 max.
Zinc		0,2 max.	0,1 max.	0,1 max.	0,1 max.
Chromium		0,1 max.	—	—	—
Titanium		0,2 max.	0,2 max.	0,2 max.	0,2 max.
Others	each	0,05 max.	0,05 max.	0,05 max.	0,05 max.
	Total	0,15 max.	0,15 max.	0,15 max.	0,15 max.
Aluminium		Remainder	Remainder	Remainder	Remainder

3.5 Heat treatment

3.5.1 Castings are to be supplied in the following conditions:

Grade Al-Mg 3 – as-manufactured
Grade Al-Si 12 – as-manufactured
Grade Al-Si 10 Mg – as-manufactured or solution heat treated and precipitation hardened
Grade Al-Si 7 Mg – solution heat treated and
(high purity) – precipitation hardened.

3.6 Mechanical tests

3.6.1 At least one tensile specimen is to be tested from each cast and, where heat treatment is involved, for each heat treatment batch from each cast. Where continuous melting is employed, 500 kg of fettled castings may be regarded as a cast.

3.6.2 The test samples are to be separately cast in moulds made from the same type of material as used for the castings. These moulds should conform to National Standards.

3.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be maintained during the preparation of test specimens.

3.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent prior to testing.

3.6.5 The results of all tensile tests are to comply with the appropriate requirements given in Table 8.3.2 and/or Table 8.3.3.

Table 8.3.2 Minimum mechanical properties for acceptance purposes of sand-cast and investment cast reference test pieces

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	150	3
Al–Si 10 Mg	M	150	2
Al–Si 10 Mg	TF	220	1
Al–Si 7 Mg	TF	230	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

Table 8.3.3 Minimum mechanical properties for acceptance purposes of chill-cast reference test piece

Alloy	Temper (*see* Note)	Tensile strength N/mm^2	Elongation %
Al–Mg 3	M	150	5
Al–Si 12	M	170	3
Al–Si 10 Mg	M	170	3
Al–Si 10 Mg	TF	240	1,5
Al–Si 7 Mg	TF	250	5

NOTE
M refers to as cast condition.
TF refers to solution heat treated and precipitation hardened condition.

3.6.6 Where the results of a test do not comply with the requirements, the re-test procedure detailed in Ch 2,1.4 is to be applied. Where castings are to be used in the heat treated condition, the re-test sample must have been heat treated together with the castings it represents.

3.7 Visual examination

3.7.1 All castings are to be cleaned and adequately prepared for inspection.

3.7.2 The accuracy and verification of dimensions are the responsibility of the manufacturer, unless otherwise agreed.

3.7.3 Before acceptance, all castings are to be presented to the Surveyor for visual examination.

3.8 Rectification of defective castings

3.8.1 At the discretion of the Surveyor, small surface blemishes may be removed by local grinding.

3.8.2 Where appropriate, repair by welding may be accepted at the discretion of the Surveyor. Such repair is to be made in accordance with an approved procedure.

3.9 Pressure testing

3.9.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence and to the satisfaction of the Surveyor.

3.10 Identification

3.10.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast and the Surveyor is to be given full facilities for tracing the casting when required.

3.10.2 All castings which have been tested and inspected with satisfactory results are to be clearly marked with the following details:
(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for the inspection.
(d) Test pressure where applicable.
(e) Date of final inspection.

3.10.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

3.11 Certification of materials

3.11.1 A LR certificate is to be issued (*see* Ch 1,3.1) giving the following particulars for each casting or batch of castings which have been accepted:
(a) Purchaser's name and order number.
(b) Description of castings and alloy type.
(c) Identification number.
(d) Ingot or cast analysis.
(e) General details of heat treatment, where applicable.
(f) Results of mechanical tests.
(g) Test pressure, where applicable.

■ *Section 4*
Aluminium/steel transition joints

4.1 Scope

4.1.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating.

4.1.2 Each individual application is to be separately approved as required by the relevant Rules dealing with design and construction.

4.2 Manufacture

4.2.1 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.2.2 The aluminium material is to comply with the requirements of Section 1 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2.

4.2.3 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give reasonable equivalence to the requirements of 4.2.2 or are approved for a specific application.

4.2.4 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.3 Visual and non-destructive examination

4.3.1 Each composite plate is to be subjected to 100 per cent visual and ultrasonic examination in accordance with a relevant National Standard to determine the extent of any unbonded areas. Unbonded areas are unacceptable and any such area plus 25 mm of surrounding sound material is to be discarded.

4.4 Mechanical tests

4.4.1 Two shear test specimens and two tensile test specimens are to be taken from each end of each composite plate for tests to be made on the bond strength. One shear and one tensile test specimen from each end are to be tested at ambient temperature after heating to the maximum allowable interface temperature, *see* 4.2.1; the other two specimens are to be tested without heat treatment.

4.4.2 Shear tests may be made on a specimen as shown in Fig. 8.4.1 or an appropriate equivalent. Tensile tests may be made across the interface by welding extension pieces to each surface or by the ram method shown in Fig. 8.4.2 or by an appropriate alternative method.

4.4.3 The shear and tensile strengths of all the test specimens are to comply with the requirements of the manufacturing specification.

4.4.4 If either the shear or tensile strength of the bond is less than the specified minimum but not less than 70 per cent of the specified minimum, two additional shear and two tensile test specimens from each end of the composite plate are to be tested and, in addition, bend tests as described in 4.4.6 and Table 8.4.1 are to be made.

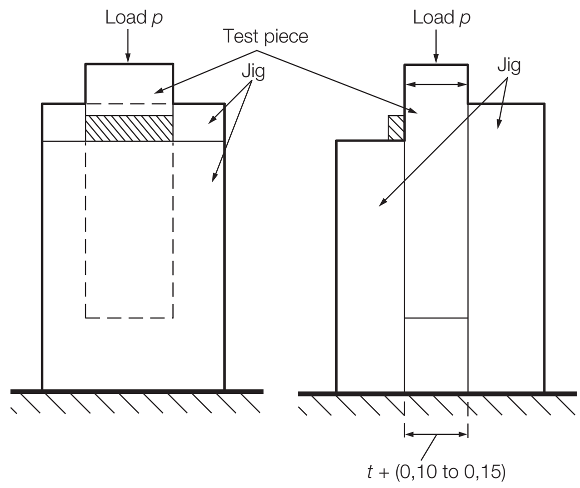


Fig. 8.4.1 Specimen and procedure for shear tests

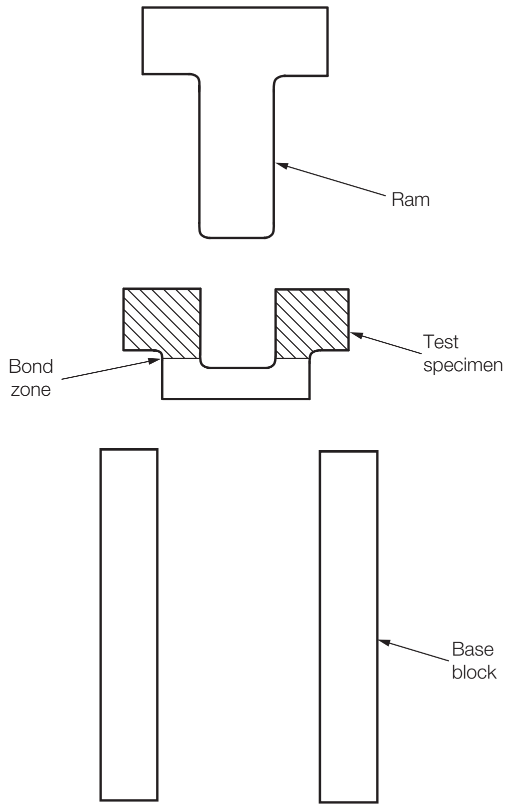


Fig. 8.4.2 Ram tensile test

Table 8.4.1 Bend tests on explosion bonded aluminium/steel composites

Type of test	Minimum bend, degrees	Diameter of former
Aluminium in tension	90	3*T*
Steel in tension	90	3*T*
Side bend	90	6*T*

NOTE
T is the total thickness of the composite plate.

4.4.5 If either the shear or tensile strength of the bond is less than 70 per cent of the specified minimum the cause is to be investigated. After evaluation of the results of this investigation, LR will consider the extent of composite plate which is to be rejected.

4.4.6 Bend tests, when required, are to be made under the following conditions, as listed in Table 8.4.1:
(a) The aluminium plate is in tension.
(b) The steel plate is in tension.
(c) A side bend is applied.

4.5 Identification

4.5.1 Each acceptable transition strip is to be clearly marked with the following particulars:
(a) LR or Lloyd’s Register and the abbreviated name of LR’s local office.
(b) Manufacturer’s name or trade mark.
(c) Identification mark for the grade of aluminium.
(d) Identification mark for the grade of steel.
The particulars are to be stamped on the aluminium surface at one end of the strip.

4.6 Certification of materials

4.6.1 A manufacturer’s certificate validated by LR is to be issued (*see* Ch 1,3.1) and as a minimum is to include the following particulars:
(a) Purchaser’s name and order number.
(b) The contract number for which the material is intended, if known.
(c) Address to which the material is dispatched.
(d) Description and dimensions of the material.
(e) Specifications or grades of both the aluminium alloy and the steel and any intermediate layer.
(f) Cast numbers of the steel and aluminium plates.
(g) Identification number of the composite plate.
(h) Mechanical test results (not required on shipping statement).

Section

■ *Section 1* Castings for propellers

1.1 Scope

1.1.1 This Section gives the requirements for copper alloy castings for one-piece propellers and separately cast blades and bosses for fixed pitch and controllable pitch propellers (CPP). These include contra-rotating propellers and propulsors fitted to podded drives and azimuth units.

1.1.2 These castings are to be manufactured and tested in accordance with the appropriate requirements of Chapters 1 and 2 and the specific requirements of this Section.

1.1.3 As an alternative to 1.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application.

1.1.4 The appropriate requirements of this Section may also be applied to the repair and inspection of propellers which have been damaged during service.

1.1.5 Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

1.2 Manufacture

1.2.1 All castings are to be manufactured at foundries approved by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 The pouring is to be carried out into dried moulds using degassed liquid metal. The pouring is to avoid turbulent flow. Special devices and/or procedures are to be used to prevent slag flowing into the mould.

1.3 Quality of castings

1.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

1.3.2 The removal and repair of defects are dealt with in 1.9 and 1.10.

1.4 Chemical composition

1.4.1 The chemical compositions of samples from each melt are to comply with the manufacturing specification approved by LR and also with the overall limits given in Table 9.1.1. In addition to carrying out chemical analysis for the elements given in the Table, it is expected that manufacturers will ensure that any harmful residual elements are within acceptable limits.

1.4.2 The use of alloys whose chemical compositions are different from those detailed in Table 9.1.1 will be given special consideration by LR.

1.4.3 The manufacturer is to maintain records of all chemical analyses, which are to be made available to the Surveyor so that he can satisfy himself that the chemical composition of each casting is within the specified limits.

Table 9.1.1 Chemical composition of propeller and propeller blade castings

Alloy designation	Chemical composition of ladle samples %							
	Cu	Sn	Zn	Pb	Ni	Fe	Al	Mn
Grade Cu 1 Manganese bronze (high tensile brass)	52–62	0,1–1,5	35–40	0,5 max.	1,0 max.	0,5–2,5	0,5–3,0	0,5–4,0
Grade Cu 2 Ni-manganese bronze (high tensile brass)	50–57	0,1–1,5	33–38	0,5 max.	2,5–8,0	0,5–2,5	0,5–2,0	1,0–4,0
Grade Cu 3 Ni-aluminium bronze	77–82	0,1 max.	1,0 max.	0,03 max.	3,0–6,0 (*see* Note)	2,0–6,0 (*see* Note)	7,0–11,0	0,5–4,0
Grade Cu 4 Mn–aluminium bronze	70–80	1,0 max.	6,0 max.	0,05 max.	1,5–3,0	2,0–5,0	6,5–9,0	8,0–20,0
NOTE For Naval ships, the nickel content is to be higher than the iron content.								

1.4.4 When a melt is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional checks as required by the Surveyor. If any foundry returns are added to the melts, the ingot manufacturer's chemical analyses are to be supplemented by frequent checks as required by the Surveyor.

1.4.5 For alloys Grade Cu 1 and Cu 2, the zinc equivalent shall not exceed 45 per cent, and is to be calculated using the following formula:

$$\text{zinc equivalent \%} = 100 - \frac{100 \times \%\text{Cu}}{100 + A}$$

where *A* is the algebraic sum of the following:

1 x % Sn
5 x % Al
–0,5 x % Mn
–0,1 x % Fe
–2,3 x % Ni

1.4.6 Samples for metallographic examination are to be prepared from the ends of test bars cast from every melt of Grade Cu 1 and Cu 2 alloys. The proportion of alpha-phase determined from the average of at least five counts is to be not less than 25 per cent.

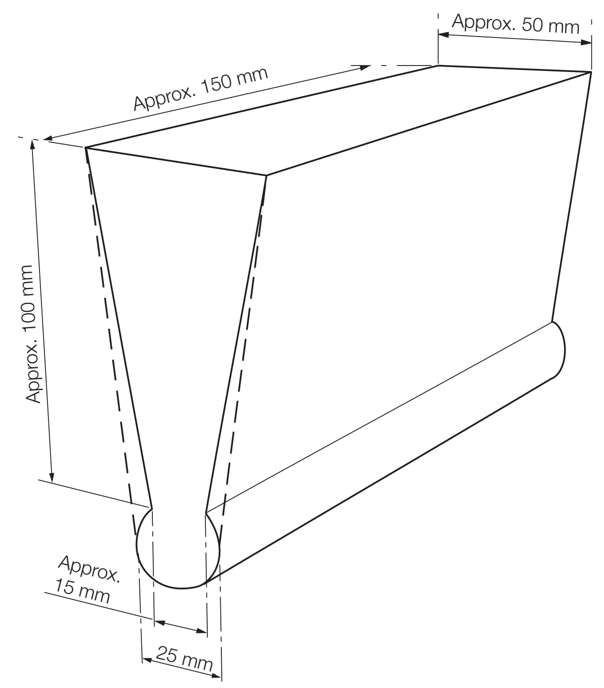


Fig. 9.1.1 Keel block type test sample

1.5 Heat treatment

1.5.1 At the option of the manufacturer, castings may be supplied in the 'as-cast' or heat treated condition. However, if heat treatment is to be applied, full details are to be included in the manufacturing specification.

1.5.2 If any welds are made in the propeller casting, stress relief heat treatment is required in order to minimise the residual stresses. Requirements concerning such heat treatment are given in 1.10.

1.6 Test material

1.6.1 Test samples are to be cast separately from each melt used for the manufacture of propeller or propeller blade castings.

1.6.2 The test samples are to be of the keel block type, generally in accordance with the dimensions given in Fig. 9.1.1 and are to be cast in moulds made from the same type of material as used for the castings.

1.6.3 The method and procedures for the identification of the test specimens, and the castings they represent, are to be agreed with the Surveyor. The identification marks are to be transferred and maintained during the preparation of test specimens.

1.6.4 Where castings are supplied in the heat treated condition, the test samples are to be heat treated together with the castings which they represent.

1.7 Mechanical tests

1.7.1 At least one tensile test specimen representative of each cast is to be prepared. The dimensions of this test specimen are to be in accordance with Fig. 2.2.1 in Chapter 2.

1.7.2 The results of all tensile tests are to comply with the requirements given in Table 9.1.2.

1.7.3 The mechanical properties of alloys whose chemical compositions do not accord with Table 9.1.1 are to comply with a manufacturing specification approved by LR.

Table 9.1.2 Mechanical properties for acceptance purposes: propeller and propeller blade castings

Alloy designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum
Grade Cu 1 Manganese bronze (high tensile brass)	175	440	20
Grade Cu 2 Ni-manganese bronze (high tensile brass)	175	440	20
Grade Cu 3 Ni-aluminium bronze	245	590	16
Grade Cu 4 Mn-aluminium bronze	275	630	18

1.8 Inspection and non-destructive examination

1.8.1 Propeller castings should be visually inspected at all stages of manufacture. The manufacturer is to draw any significant imperfections to the attention of the Surveyor. Such imperfections are to be verified in accordance with 1.9.

1.8.2 All finished castings are to be subjected to a comprehensive visual examination by the Surveyor, including internal surfaces such as the bore and bolt holes.

1.8.3 For the purpose of these requirements, the blades of propellers, including CPP blades, are divided into three severity Zones A, B and C as shown in Fig. 9.1.2 and detailed in 1.8.4 for blades having skew angles of 25° or less and 1.8.5 for blades having skew angles of greater than 25°.

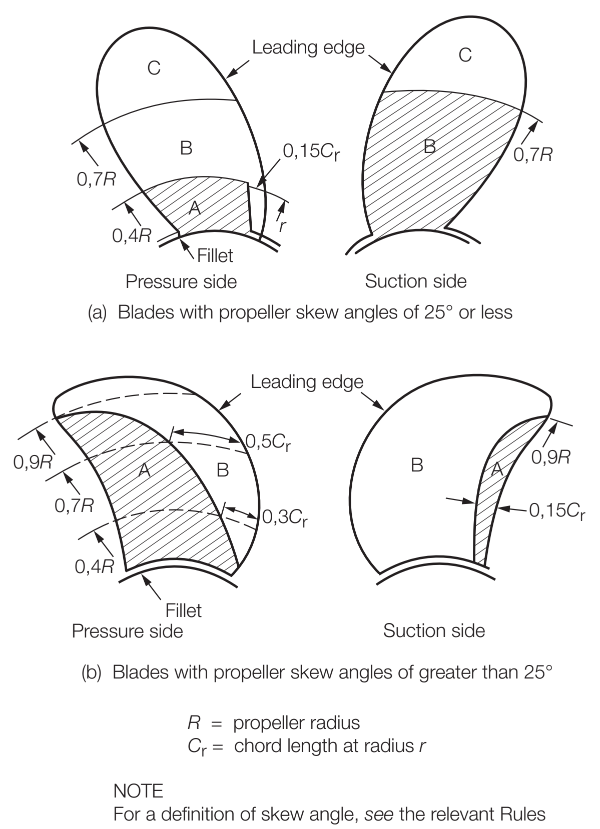


Fig. 9.1.2 Severity zones in all propeller blades

1.8.4 **Skew angles of 25° or less:**

- Zone A is the area on the pressure side of the blade from and including the root fillet to 0,4*R* and bounded by the trailing edge and by a line at a distance 0,15 times the chord length from the leading edge.
- Zone B includes the areas inside 0,7*R* on both sides of the blade, excluding Zone A.
- Zone C includes the areas outside 0,7*R* on both sides of the blade.

1.8.5 **Skew angles of greater than 25°**:

- Zone A is the area on the pressure side of the blade bounded by, and including, the root fillet and a line running from the junction of the leading edge with the root fillet to the trailing edge at 0,9*R* and passing through the mid-point of the chord at 0,7*R* and a point situated at 0,3 of the chord length from the leading edge at 0,4*R*.
- Zone A also includes the area along the trailing edge on the suction side of the blade from the root to 0,9*R* and with its inner boundary at 0,15 of the chord length tapering to meet the trailing edge at 0,9*R*.
- Zone B constitutes the whole of the remainder of the blade surfaces.

1.8.6 In propeller blades with continuously loaded tips (CLT), the whole of the tip plate and the adjoining blade to a distance of 100 mm is to be regarded as severity Zone B, *see* Fig. 9.1.3. For propellers with diameters less than 2 m, the width of this zone may be reduced to one tenth of the propeller radius.

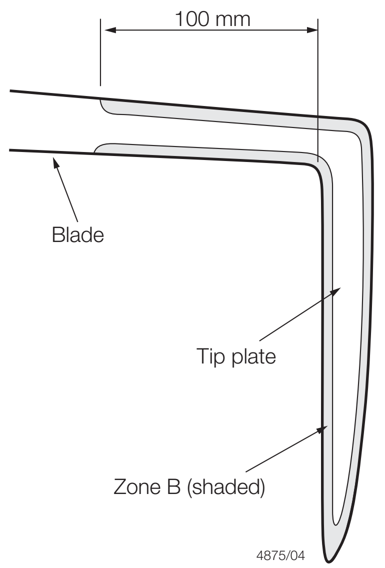
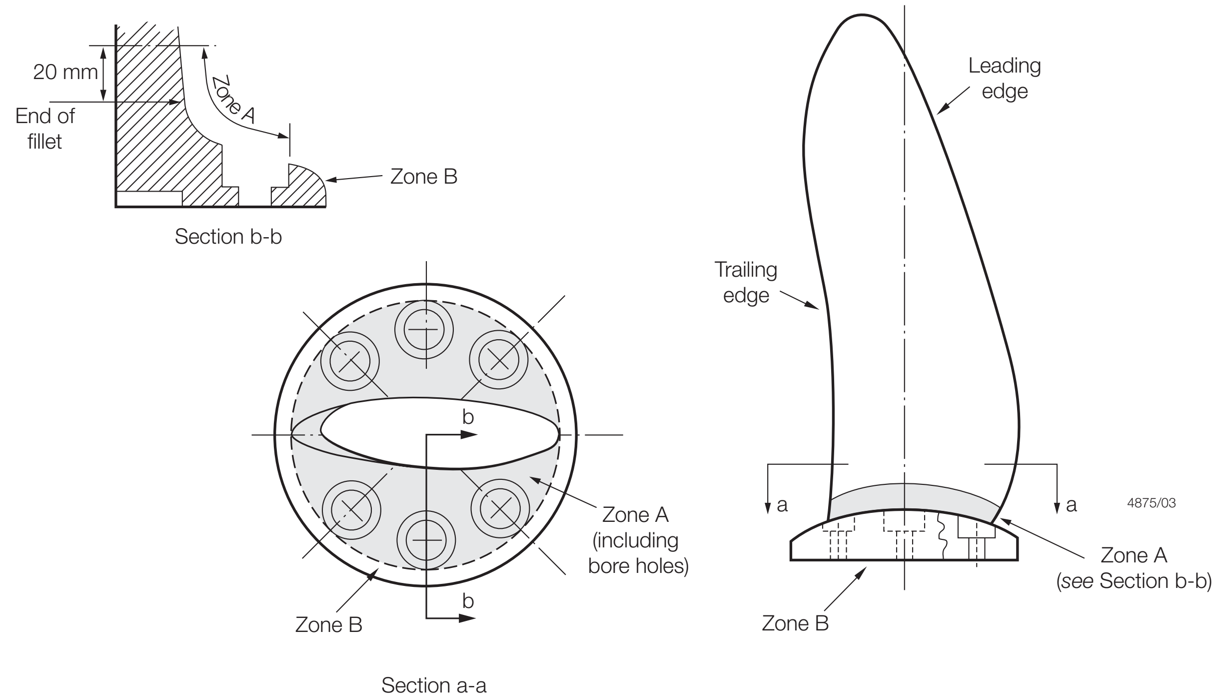


Fig. 9.1.3
Severity Zone B at Continuously loaded blade tip

1.8.7 In addition, the palm of a CPP blade is divided into severity Zones A and B as shown in Fig. 9.1.4.

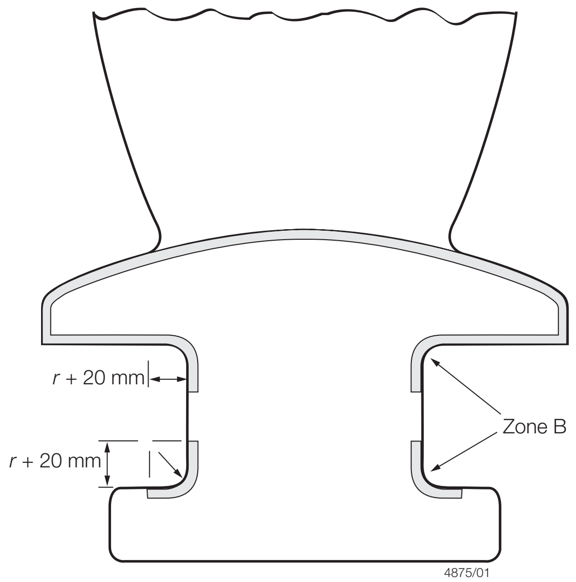
1.8.8 If a CPP blade has an integrally cast journal, the fillets of the journal and the adjoining material up to a distance of 20 mm from the fillet run-outs are to be regarded as Zone B, as indicated in Fig. 9.1.5. The remainder of the surface of the journal may be regarded as Zone C.

1.8.9 Hubs of controllable pitch propellers are to contain a Zone A region at each blade port as shown in Fig. 9.1.6. The remainder may be regarded as Zone C.



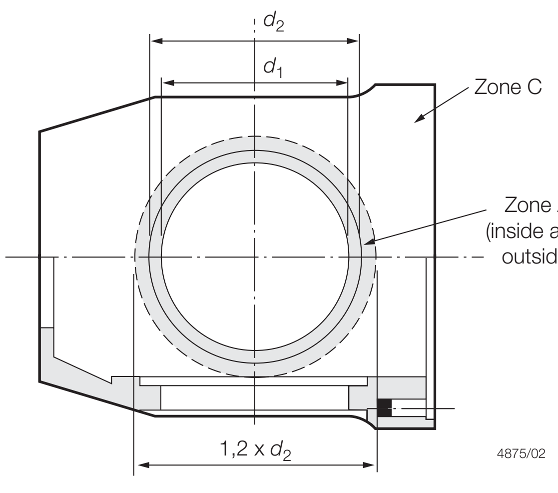
The surfaces of blades are to be divided into severity zones in accordance with Fig. 9.1.2

Fig. 9.1.4 Severity zones for controllable pitch propeller blades



The surfaces of the journal which are not shaded are to be regarded as severity Zone C

Fig. 9.1.5
Severity zones in integrally cast CPP blade journals



(d_1 and d_2 = diameters)

Fig. 9.1.6
Severity zones for controllable pitch propeller hub

1.8.10 On completion of machining and grinding, the whole surface of each casting is to be subjected to a dye penetrant inspection in accordance with a procedure acceptable to LR.

1.8.11 All dye penetrant inspections on Zone A areas in the finished condition are to be made in the presence of the Surveyor.

1.8.12 Dye penetrant inspections on Zones B and C are to be performed by the manufacturer and may be witnessed at the Surveyor's request.

1.8.13 The surface to be inspected shall be divided into reference areas of 100 cm^2. The indications detected shall, with respect to their size and number, not exceed the values given in Table 9.1.3. The area shall be taken in the most unfavourable location relative to the indication being evaluated.

1.8.14 Indications exceeding the acceptance standard in Table 9.1.3 shall be repaired in accordance with 1.9.

1.8.15 All defects requiring repair by welding in new propeller castings are to be recorded on sketches showing their locations and dimensions. Copies of these sketches are to be presented to the Surveyor prior to repair.

1.8.16 Where repairs have been made either by grinding or welding, the repaired areas are to be subjected to dye penetrant inspection in the presence of the Surveyor, regardless of their location.

1.8.17 Where no welds have to be made on a casting, the manufacturer is to provide the Surveyor with a statement that this is the case.

1.8.18 Where it is suspected that a casting contains internal defects, radiographic and/or ultrasonic examination may be required by the Surveyor. The acceptance criteria are to be agreed between the manufacturer and LR in accordance with a recognised standard. The standard ASTM E272-99 (Severity Level 2) or equivalent is to be the radiographic acceptance standard for copper alloy castings. Ultrasonic testing of Cu 1 and Cu 2 is not considered in these Rules. For Cu 3 and Cu 4, ultrasonic inspection of defects may be possible and is to comply with the requirements for steel castings.

1.8.19 The measurement of dimensional accuracy is the responsibility of the manufacturer but the report on dimensional inspection is to be presented to the Surveyor who may require checks to be made and to witness such checks.

1.8.20 Static balancing is to be carried out on all propellers in accordance with the approved plan. Dynamic balancing is necessary for propellers running above 500 rpm.

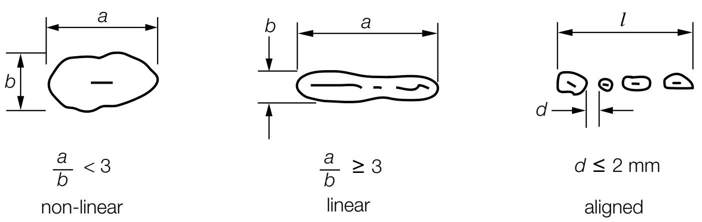
1.9 Rectification of defective castings

1.9.1 The rectification of defective propeller and propeller blade castings is to be carried out in accordance with the requirements given in 1.9.2 to 1.9.12.

Table 9.1.3 Allowable number and size of dye penetrant indications in a reference area of 100 cm^2 (*see* Note 1)

Severity Zones	Max. total number of indications	Type of indications (*see* Note 2)	Max. number of each type (*see* Notes 3 and 4)	Max. acceptable value for 'a' or '*l*' of indications (mm) (*see* Note 2)
A	7	Non-linear	5	4
		Linear	2	3
		Aligned	2	3
B	14	Non-linear	10	6
		Linear	4	6
		Aligned	4	6
C	20	Non-linear	14	8
		Linear	6	6
		Aligned	6	6

NOTES
1. The reference area is defined as an area of 0,1 m^2, which may be square or rectangular, with the major dimension not exceeding 250 mm. The area shall be taken in the most unfavourable location relative to the indication being evaluated.
2. Non-linear, linear and aligned indications are defined as follows:



3. Only indications that have any dimension greater than 1,5 mm shall be considered relevant.
4. Single non-linear indications less than 2 mm in Zone A and less than 3 mm in other zones may be disregarded.
5. The total number of non-linear indications may be increased to the maximum total number, or part thereof, represented by the absence of linear or aligned indications.

1.9.2 The rectification of small indications within the acceptance standard of Table 9.1.3 is not generally required except where they occur in closely spaced groups.

1.9.3 Where, in the surface of the end face or bore of a propeller boss, local pores are present which do not themselves adversely affect the strength of the casting, they may be filled with a suitable plastic filler after the appropriate preparation of the defective area. The foundry is to maintain records and details of all castings which have been so rectified.

1.9.4 Where unacceptable defects are found in a casting, they are to be removed by mechanical means, and the surfaces of the resulting depressions are subsequently to be ground smooth. Complete elimination of the defects is to be proved by adequate dye penetrant inspection.

1.9.5 Shallow grooves or depressions resulting from the removal of defects may, at the discretion of the Surveyor, be accepted provided that they will cause no appreciable reduction in the strength of the castings and that they are suitably blended by grinding.

1.9.6 Welded repairs are to be undertaken only when they are considered to be necessary and approved by the Surveyor. In general, welds having an area less than 5 cm^2 are to be avoided.

1.9.7 All weld repairs are to be carried out in accordance with qualified procedures by suitably qualified welders, and are to be completed to the satisfaction of the Surveyor. Records are to be made available to the Surveyor.

1.9.8 Welding is generally not permitted in Zone A and will only be allowed after special consideration.

1.9.9 Prior approval by the Surveyor is required for any welds in Zone B. Complete details of the repair procedure are to be submitted for each case.

1.9.10 Repair by welding is allowed in Zone C provided that there is compliance with 1.9.6 and 1.9.7.

1.9.11 The maximum area of any single repair and the maximum total area of repair in any one zone or region are given in Table 9.1.4.

1.9.12 Where it is proposed to exceed the areas given in Table 9.1.4, the nature and extent of the repair work are to be approved by the Surveyor before commencement of the repair.

1.10 Weld repair procedure

1.10.1 Welding is to be carried out under cover in positions free from draughts and adverse weather conditions.

1.10.2 The manufacturer is to submit a detailed welding procedure specification covering the weld preparation, welding parameters, filler metal, preheating, post-weld heat treatment and inspection procedures.

Table 9.1.4 Permissible rectification of new propellers by welding

<table>
<tr><th>Severity zone or region</th><th>Maximum individual area of repair</th><th>Maximum total area of repairs</th></tr>
<tr><td>Zone A</td><td colspan="2">Weld repairs not generally permitted</td></tr>
<tr><td>Zone B</td><td rowspan="2">60 cm^2 or 0,6% x S whichever is the greater</td><td rowspan="2">200 cm^2 or 2% x S, whichever is the greater in combined Zones B and C but not more than 100 cm^2 or 0,8% x S, whichever is the greater, in Zone B on the pressure side</td></tr>
<tr><td>Zone C</td></tr>
<tr><td>Other regions (see Note)</td><td>17 cm^2 or 1,5% area of the region whichever is the greater</td><td>50 cm^2 or 5% x area of the region whichever is the greater</td></tr>
<tr><td colspan="3">where S = area of one side of a blade = $0,79 \dfrac{D^2 B}{N}$
D = finished diameter of propeller
B = developed area ratio
N = number of blades</td></tr>
<tr><td colspan="3">NOTE
Other regions include:
(a) the bore;
(b) the forward and aft faces of the boss;
(c) the outer surface of the boss to the start of the blade root fillets;
(d) the inner face of a CPP blade palm;
(e) all surfaces of CPP nose cones;
(f) the surfaces of integral journals to CPP blades other than the fillets.</td></tr>
</table>

1.10.3 Before welding is started, Welding Procedure Qualification tests are to be carried out and witnessed by the Surveyor. Each welder is to be qualified to carry out the proposed welding using the same process, consumable and position which are to be used for the repair.

1.10.4 Defects to be repaired by welding are to be removed completely by mechanical means (e.g. grinding, chipping or milling). Removal of defects in accordance with the requirements for Zone A is to be demonstrated by dye penetrant inspection in the presence of the Surveyor. The excavation is to be prepared in a manner which will allow good fusion and is to be clean and dry.

1.10.5 Metal arc welding with the electrodes or filler wire used in the procedure tests is to be used for all types of repairs. Welds should preferably be made in the downhand (flat) position. Where necessary, suitable preheat is to be applied before welding, and the preheat temperature is to be maintained until welding is completed.

1.10.6 When flux coated electrodes are used they are to be dried immediately before use, in accordance with the manufacturer's instructions.

1.10.7 All slag, undercuts and other defects are to be removed before the subsequent run is deposited.

1.10.8 With the exception given in 1.10.9, all weld repairs in areas of solid propellers exposed to sea-water, and all repairs to separately cast blades, are to be stress relief heat treated.

1.10.9 Stress relief heat treatment is not mandatory after welding Grade Cu 3 castings in Zone C unless a welding consumable susceptible to stress corrosion (e.g. complying with the composition range of Grade Cu 4) is used. All welds in Zones A and B however, must be stress relieved by heat treatment, regardless of alloy.

1.10.10 Propeller and propeller blades are to be stress relieved within the following temperature ranges:

alloy Grades Cu 1 and Cu 2	350°C to 550°C
alloy Grade Cu 3	450°C to 500°C
alloy Grade Cu 4	450°C to 600°C

Soaking times are to be in accordance with Table 9.1.5, and subsequent cooling from the soaking temperature is to be suitably controlled to minimise residual stresses and is not to exceed 50°C per hour until the temperature is below 200°C. Care should be taken to avoid heating castings in the Grade Cu 3 alloy at temperatures between 300° and 400°C for prolonged periods.

Table 9.1.5 Soaking times for stress relief heat treatment of copper alloy propellers

Stress relief temperature °C (*see* Notes)	Alloy Grade Cu1 and Cu2		Alloy Grade Cu3 and Cu4	
	Hours per 25 mm of thickness	Maximum recommended total time hours	Hours per 25 mm of thickness	Maximum recommended total time hours
350	5	15	—	—
400	1	5	—	—
450	1/2	2	5	15
500	1/4	1	1	5
550	1/4	1/2	1/2	2
600	—	—	1/4	1

NOTES
1. Treatment at 550°C is not applicable to alloy Grade Cu3.
2. Treatment at 600°C is only applicable to alloy Grade Cu4.

1.10.11 Stress relief heat treatment is to be carried out, where possible, in furnaces having suitable atmosphere and temperature control. Sufficient thermocouples are to be attached to the casting to measure the temperature at positions of extremes of thickness.

1.10.12 As an alternative to 1.10.11, local stress relief heat treatment may be accepted, provided that the Surveyor is satisfied that the technique will be effective and that adequate precautions are taken to prevent the introduction of detrimental temperature gradients. Where local stress relief heat treatment is approved, adequate temperature control is to be provided. The area of the propeller or blade adjacent to the repair is to be suitably monitored and insulated to ensure that the required temperature is maintained and that temperature gradients are moderate. Care should be taken to select the shape of an area to be heat treated which will minimise residual stresses.

1.10.13 On completion, welds are to be ground smooth for visual examination and dye penetrant inspection. Where a propeller or propeller blade is to be stress relief heat treated, a visual examination is to be made before heat treatment, and both visual and dye penetrant examinations are to be made after the stress relief heat treatment. Irrespective of location, all weld repairs are to be assessed according to Zone A in Table 9.1.3.

1.10.14 The foundry is to maintain full records detailing the weld procedure, heat treatment and extent and location on drawings of repairs made to each casting. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

1.10.15 LR reserves the right to restrict the amount of repair work accepted from a manufacturer when it appears that repetitive defects are the result of improper foundry techniques or practices.

1.11 Identification

1.11.1 Castings are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all castings which have been accepted:

(a) Identification mark which will enable the full history of the item to be traced.
(b) Alloy grade.
(c) LR or Lloyd's Register and the abbreviated name of LR local office.
(d) Personal stamp of Surveyor responsible for the final inspection.
(e) Date of final inspection.
(f) Skew angle, if in excess of 25°. *See* Pt 5, Ch 7,1 of the Rules for Ships for the definition of skew angle.

1.12 Certification of materials

1.12.1 A LR certificate is to be issued for each propeller, *see* Ch 1,3.1

1.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting:

(a) Purchaser's name and order number.
(b) Description of casting.
(c) Alloy designation and/or trade name.
(d) Identification number of casting.
(e) Cast identification number if different from (d).
(f) Details of heat treatment, where applicable.
(g) Skew angle, if in excess of 25°. *See* the relevant Rules for the definition of skew angle.
(h) Final weight of casting.
(j) Results of non-destructive tests and details of test procedures.
(k) Proportion of alpha-structure for Cu1 and Cu2 alloys.
(l) Results of mechanical tests.
(m) A sketch showing the location and extent of welding repairs (if any).

■ *Section 2*
Castings for valves, liners and bushes

2.1 Scope

2.1.1 This Section makes provision for copper alloy castings for valves, liners, bushes and other fittings intended for use in the construction of ships, other marine structures, machinery and pressure piping systems.

2.1.2 Castings are to be manufactured and tested in accordance with Chapters 1 and 2, and also with the requirements given in this Section.

2.1.3 As an alternative to 2.1.2, castings which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

2.2 Manufacture

2.2.1 Castings are to be manufactured at foundries approved by LR.

2.3 Quality of castings

2.3.1 All castings are to be free from surface or internal defects which would be prejudicial to their proper application in service.

2.4 Chemical composition

2.4.1 The chemical composition is to comply with the requirements of a National or International Standard and, where appropriate, with the limits for the principal elements of the preferred alloys listed in Tables 9.2.1 and 9.2.2.

2.4.2 With the exception given in 2.4.3, chemical analysis is required on each cast.

2.4.3 Where a cast is wholly prepared from ingots for which an analysis is already available, and provided that no significant alloy additions are made during melting, the ingot maker's certified analysis can be accepted subject to occasional check tests as requested by the Surveyor. The frequency of these check tests should, as a minimum, be one in every ten casts. If one of these check analyses fails to comply with the specification, checks are to be made on the previous and subsequent melts. If one or both of these further analyses is unsatisfactory, chemical analysis is to be carried out on all further melts until the Surveyor is satisfied that a return can be made to the use of occasional check tests.

2.5 Heat treatment

2.5.1 Where required by the specification, castings may be supplied in either the 'as-cast' or heat treated condition.

2.5.2 Where castings are supplied in a heat treated condition, the test samples are to be heat treated with the castings they represent prior to the preparation of the tensile test specimens.

2.6 Test material

2.6.1 Test material sufficient for the tests specified in 2.6.4 and for possible re-test purposes is to be provided for each cast of material.

2.6.2 The test material is to be separately cast into moulds made of the same material as that used for the castings they represent.

2.6.3 For the alloys listed in Table 9.2.1, sand cast test bars are generally to be in accordance with Fig. 9.2.1.

2.6.4 For the alloys listed in Table 9.2.2, keel block type test samples are to be in accordance with Fig. 9.1.1.

Table 9.2.1 Chemical compositions of long freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition						Typical applications
		Cu	Sn	Zn	Pb	Ni	P	
Phosphor bronze	Cu Sn11P Cu Sn12	87,0 – 89,5 85,0 – 88,5	10,0 – 11,5 11,0 – 13,0	0,05 max. 0,50 max.	0,25 max. 0,7 max.	0,10 max. 2,0 max.	0,5 – 1,0 0,60 max.	Liners, bushes, valves and fittings
Gunmetal	Cu Sn10 Zn2	Remainder	9,5 – 10,5	1,75 – 2,75	1,5 max.	1,0 max.	—	Liners, valves and fittings
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	83,0 – 87,0 85,0 – 89,0 81,0 – 85,0 86,0 – 90,0	4,0 – 6,0 6,0 – 8,0 6,0 – 8,0 5,5 – 6,5	4,0 – 6,0 1,5 – 3,0 2,0 – 5,0 3,0 – 5,0	4,0 – 6,0 2,5 – 3,5 5,0 – 8,0 1,0 – 2,0	2,0 max. 2,0 max. 2,0 max. 1,0 max.	0,10 max. 0,10 max. 0,10 max. 0,05 max.	Bushes, valves and fittings
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	78,0 – 82,0 80,0 – 87,0 74,0 – 80,0 70,0 – 78,0	9,0 – 11,0 4,0 – 6,0 6,0 – 8,0 4,0– 6,0	2,0 max. 2,0 max. 2,0 max. 2,0 max.	8,0 – 11,0 8,0 – 10,0 13,0 – 17,0 18,0 – 23,0	2,0 max. 2,0 max. 0,5 – 2,0 0,5 – 2,5	0,10 max. 0,10 max. 0,10 max. 0,10 max.	Bushes

Table 9.2.2 Chemical compositions of short freezing range alloys: principal elements only

Alloy type	Designation	Chemical composition								Typical applications
		Cu	Ni	Fe	Mn	Cr	Nb	Si	Al	
Copper 30% nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si (*see* Note 1)	64,5 min. Remainder Remainder	29,0–31,0 29,0–31,0 29,0–32,0	0,5–1,5 0,5–1,5 0,5–1,0	0,6–1,2 0,6–1,2 0,5–1,0	– – 1,5–2,0	– 0,5–1,0 –	0,1 max. 0,3–0,7 0,15–0,50	– – –	Flanges, valves and fittings
Copper 10% nickel	Cu Ni10 Fe1 Mn1	84,5 min.	9,0–11,0	1,0–1,8	1,0–1,5	–	1,0 max.	0,10 max.	–	Flanges, valves and fittings
Aluminium bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	76,0–83,0 72,0–78,0	4,0–6,0 (*see* Note 2) 4,0–7,5 (*see* Note 2)	4,0–5,5 (*see* Note 2) 4,0–7,0 (*see* Note 2)	3,0 max. 2,5 max.	– –	– –	0,1 max. 0,1 max.	8,5–10,5 10,0–12,0	Bushes, valves and fittings

NOTES
1. Normally alloy Cu Ni30 Cr2 Fe Mn Si contains 0,1 to 0,25% titanium and 0,05 to 0,15% zirconium.
2. For Naval ships, the nickel content is to be higher than the iron content.

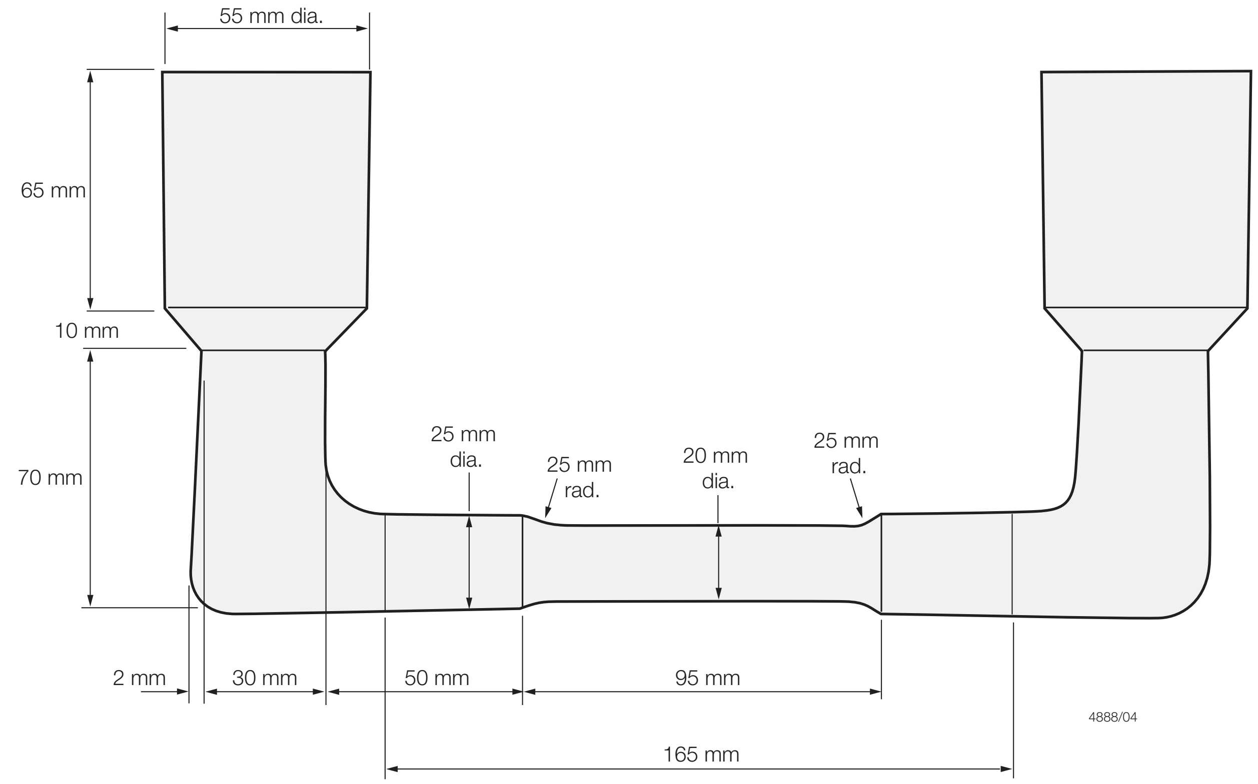


Fig. 9.2.1 Sand cast test bars for long freezing range alloys

2.6.5 If it is proposed to use any other form of test bar, this is to be agreed in advance with the Surveyor.

2.6.6 As an alternative, for liners and bushes, the test material may be taken from the ends of the castings.

2.7 Mechanical tests

2.7.1 A tensile test specimen is to be prepared from each test sample. The dimensions of the specimens are to comply with Fig. 2.2.1 or Fig. 2.2.2 in Chapter 2.

2.7.2 The results of all tests are to comply with the appropriate requirements given in Tables 9.2.3 and 9.2.4.

Table 9.2.3 Mechanical properties of long freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Phosphor bronze	Cu Sn11 P Cu Sn12	130 140	170 150	250 260	330 280	5 7	4 5
Gunmetal	Cu Sn10 Zn2	130	130	270	250	13	5
Leaded gunmetal	Cu Sn5 Zn5 Pb5 Cu Sn7 Zn2 Pb3 Cu Sn7 Zn4 Pb7 Cu Sn6 Zn4 Pb2	90 130 120 110	110 130 120 110	200 230 230 220	250 260 260 240	13 14 15 15	13 12 12 12
Leaded bronze	Cu Sn10 Pb10 Cu Sn5 Pb9 Cu Sn7 Pb15 Cu Sn5 Pb20	80 60 80 70	110 90 90 80	180 160 170 150	220 200 200 170	8 7 8 5	6 6 7 6

NOTES
1. The 0,2% proof stress values are given for information purposes only and, unless otherwise agreed, are not required to be verified by test.
2. Castings may be supplied in the chill cast condition in which case the mechanical properties requirements are to be in accordance with a specification agreed by LR.

Table 9.2.4 Mechanical properties of short freezing range alloys for acceptance purposes

Alloy type	Designation	0,2% proof stress N/mm^2 minimum (*See* Note 1)		Tensile strength N/mm^2 minimum		Elongation on 5,65 $\sqrt{S_o}$ % minimum	
		Sand	Centrifugal	Sand	Centrifugal	Sand	Centrifugal
Copper 30% Nickel	Cu Ni30 Fe1 Mn1 Cu Ni30 Fe1 Mn1 Nb Si Cu Ni30 Cr2 Fe Mn Si	120 230 250	120 — —	340 440 440	340 — —	18 18 18	18 — —
Copper 10% Nickel	Cu Ni10 Fe1 Mn1	120	100	280	280	20	25
Aluminium Bronze	Cu Al10 Fe5 Ni5 Cu Al11 Fe6 Ni6	250 320	280 380	600 680	650 750	13 5	13 5

2.8 Inspection

2.8.1 All castings are to be cleaned and adequately prepared for inspection. Before acceptance, all castings are to be presented to the Surveyor for visual examination. This is to include the examination of internal surfaces, where applicable.

2.8.2 For valves and other pressure components, dye penetrant inspection is required and the Surveyor is to witness the tests. Unless otherwise agreed, the acceptance criteria to be applied are to meet the requirements of Table 9.2.5, or equivalent.

2.8.3 The accuracy and verification of dimensions are the responsibility of the manufacturer. However, the report on dimensional inspection is to be presented to the Surveyor who may request to witness confirmatory measurements.

Table 9.2.5 Visual and surface NDE acceptance criteria for valves and pressure components

Defect type	Acceptance criteria for visual and surface NDE, *see* Note
Linear indications	Not permitted
Porosity	Individual pores are not to exceed 3 mm diameter bleed out, and the sum of the diameters of all indications in an area of 70 x 70 mm is not to exceed 24 mm^2

NOTE
Inspection is to be in accordance with a procedure acceptable to LR.

2.9 Rectification of defective castings

2.9.1 Subject to the prior approval of the Surveyor, castings containing local porosity may be rectified by impregnation with a suitable plastic filler provided that the extent of the porosity is such that it does not adversely affect the strength of the casting.

2.9.2 Proposals to repair a defective casting by welding are to be submitted to the Surveyor before this work is commenced. The Surveyor is to be satisfied that the number, position and size of the defects are such that the castings can be efficiently repaired.

2.9.3 Where approval is given for the repair by welding, complete elimination of the defects is to be proven by adequate non-destructive testing.

2.9.4 All welding is to be in accordance with an approved and qualified weld procedure and carried out by a qualified welder.

2.9.5 A statement and/or sketch detailing the extent and position of all weld repairs is to be prepared by the manufacturer as a permanent record. These records are to be available for review by the Surveyor, and copies of individual records are to be supplied to the Surveyor on request.

2.9.6 The alloys listed in Table 9.2.1 are not satisfactory for repair by welding which is generally not permitted. Weld repairs may, however, be considered in special circumstances provided that a suitable procedure, with proof of previous satisfactory repairs is submitted to the Surveyor.

2.9.7 The welding during manufacture of liners is not permitted in any alloy containing more than 0,5 per cent lead.

2.10 Pressure testing

2.10.1 Where required by the relevant Rules, castings are to be pressure tested before final acceptance. Unless otherwise agreed, these tests are to be carried out in the presence of the Surveyors and are to be to their satisfaction.

2.11 Identification

2.11.1 The manufacturer is to adopt a system of identification which will enable all finished castings to be traced to the original cast, and the Surveyor is to be given full facilities for tracing the casting when required.

2.11.2 Before acceptance, all castings which have been tested and inspected with satisfactory results are to be clearly marked by the manufacturer with the following details:

(a) Identification number, cast number or other markings which will enable the full history of the casting to be traced.
(b) LR or Lloyd's Register and the abbreviated name of LR's local office.
(c) Personal stamp of the Surveyor responsible for inspection.
(d) Test pressure, where applicable.
(e) Date of final inspection.

2.11.3 Where small castings are manufactured in large numbers, modified arrangements for identification may be specially agreed with the Surveyor.

2.12 Certification of materials

2.12.1 A LR certificate is to be issued, *see* Ch 1,3.1.

2.12.2 The manufacturer is to provide the Surveyor with the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Description of castings and alloy grade.
(c) Identification number.
(d) Ingot or cast analysis.
(e) Full details of heat treatment, where applicable.
(f) Mechanical test results.
(g) Test pressure, where applicable.

2.12.3 In addition to 2.12.2, the manufacturer is to provide, where applicable, a statement and/or sketch detailing the extent and position of all weld repairs made to each casting.

■ *Section 3* Tubes

3.1 Scope

3.1.1 Provision is made in this Section for seamless copper and copper alloy tubes intended for use in condensers, heat exchangers and pressure piping systems.

3.1.2 Tubes for Class I and II pressure systems (as defined in the relevant Rules) are to be manufactured and tested in accordance with the requirements of Chapters 1 and 2 and the requirements of this Section.

3.1.3 As an alternative to 3.1.2, tubes which comply with National or proprietary specifications may be accepted provided that these specifications give reasonable equivalence to the requirements of this Section or alternatively are approved for a specific application. Generally, survey and certification are to be carried out in accordance with the requirements of Chapter 1.

3.1.4 Tubes for Class III pressure systems are to be manufactured and tested in accordance with the requirements of a National or International Standard recognised by LR. The manufacturer's test certificate will be acceptable and is to be provided for each batch of material.

3.2 Manufacture

3.2.1 Tubes for Class I and II pressure systems are to be manufactured at a works approved by LR for the grade of material being supplied.

3.2.2 Tubes for Class III pressure systems are not required to be manufactured at a works approved by LR.

3.3 Quality

3.3.1 Tubes are to be clean and free from surface and internal defects and residues from manufacturing operations.

3.3.2 The tubes are to be supplied in smooth, round, straight lengths, free from deleterious films in the bore. The ends are to be cut clean and square with the axis of the tube and are to be de-burred.

3.4 Dimensional tolerances

3.4.1 The tolerances on the wall thickness and diameter of the tubes are to be in accordance with a National or International Standard recognised by LR.

3.4.2 The measurement of dimensional accuracy and compliance with the specification are the responsibility of the manufacturer, but the reports are to be made available to the LR Surveyors, who may require checks to be made in their presence.

3.5 Chemical composition

3.5.1 The chemical composition is to comply with the requirements of a National or International Standard recognised by LR and comply with the base limits for the principal elements given in Table 9.3.1.

3.6 Heat treatment

3.6.1 Copper-phosphorus and aluminium brass tubes are to be supplied in the annealed condition. Aluminium brass tubes may additionally be required to be given a suitable stress relieving heat treatment when subjected to a cold straightening operation after annealing.

3.6.2 Tubes in the copper-nickel iron alloys are to be supplied in a solution heat treated condition to ensure that no iron rich phases are present.

3.7 Mechanical tests

3.7.1 Tubes are to be presented for test in batches of 300 lengths. A batch is to consist of tubes of the same size, manufactured from the same material grade.

3.7.2 At least one length is to be selected at random from each batch and subjected to the following tests:

(a) Tensile test.
(b) Flattening test.
(c) Drift expanding test.

3.7.3 The procedures for mechanical tests and the dimensions of the test specimens are to be in accordance with Chapter 2.

3.7.4 The flattening test is to be continued until the interior surfaces of the tube meet.

3.7.5 For the drift expanding test, the mandrel is to have an included angle of 45°.

3.7.6 The results of all mechanical tests are to comply with the appropriate requirements given in Table 9.3.2.

3.7.7 At the discretion of the Surveyor, a modified testing procedure may be adopted for small quantities of materials. In such cases, these may be accepted on the manufacturer's declared chemical composition and hardness tests or other evidence of satisfactory properties.

Table 9.3.1 Chemical composition of principal elements only

Designation	Chemical composition %								
	Cu	As	P	Fe	Pb	Ni	Al	Mn	Zn
Copper-phosphorus deoxidised–non-arsenical	99,85 min.	–	0,013–0,050	—	—	—	—	—	—
Copper-phosphorus deoxidised–arsenical	99,2 min.	0,30–0,50	0,013–0,050		—	—	—	—	—
Aluminium brass	76,0–79,0	0,02–0,06	—	0,06 max.	0,07 max.	—	1,8–2,5	—	Remainder
90/10 Copper-nickel-iron (*see* Note)	Remainder	—	—	1,0-2,0	—	9,0–11,0	—	0,5–1,0	—
70/30 Copper-nickel-iron (*see* Note)	Remainder	—	—	0,40–1,00	—	29,0–33,0	—	0,5–1,5	—

NOTE
Where the purchaser specifies that the product is intended for subsequent welding applications, the following limits will apply:

Zn	0,50% max.	S	0,02% max.
Pb	0,02% max.	C	0,05% max.
P	0,02% max.		

Table 9.3.2 Mechanical properties for acceptance purposes

Designation	0,2% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on $5{,}65\sqrt{S_o}$ % minimum	Drift expansion test % minimum	Grain size mm maximum (*see* Note)
Copper-phosphorus deoxidised–non-arsenical	65	220	40	40	—
Copper-phosphorus deoxidised–arsenical	65	220	40	40	—
Aluminium brass	125	320	40	30	0,045
90/10 Copper-nickel-iron	100	270	30	30	0,045
70/30 Copper-nickel-iron	120	360	30	30	0,045

NOTE
When a maximum grain size is specified, the structure is to be completely re-crystallised. The manufacturer is to guarantee the grain size, but testing of each batch will not be required.

3.8 Visual examination

3.8.1 All tubes are to be visually examined. The manufacturer is to provide adequate lighting conditions to enable an internal and external examination of the tubes to be carried out.

3.8.2 The inner and outer surfaces are to be clean and smooth but may have a superficial, dull iridescent film on both the inner and outer surfaces.

3.9 Stress corrosion cracking test

3.9.1 This is an accelerated test for detecting the presence in tubes of internal stresses which might result in failure, in storage or in service, due to stress corrosion cracking.

3.9.2 The test is applicable only to aluminium brass and copper-nickel-iron tubes.

3.9.3 The test specimen is to consist of a 150 mm length cut from the tube selected for mechanical tests in accordance with 3.7.2.

3.9.4 The test is to be carried out in accordance with a National or International Standard recognised by LR or by the test method given in 3.9.5.

3.9.5 The test specimen is to be immersed in a mercurous nitrate solution at room temperature for 30 minutes. Aluminium brass specimens are to be examined for cracks immediately after rinsing, while copper-nickel-iron specimens are to be examined 24 hours after rinsing.

3.9.6 Should any specimen fail to meet the requirements of this test, then all tubes represented by that specimen are to be withdrawn. The tubes may be re-submitted after stress relieving treatments for full testing in accordance with 3.7 and 3.9.

3.10 Hydraulic test

3.10.1 Each tube is to be subjected to a hydraulic test at the manufacturer's works.

3.10.2 The hydraulic test pressure is to be determined from the following formula, except that the maximum test pressure need not exceed 70 bar:

$$P = \frac{20st}{D}$$

where

P = test pressure, in bar
D = nominal outside diameter, in mm
t = nominal wall thickness, in mm
s = 40 for copper-phosphorus
60 for Al-brass and
90/10 copper nickel iron
75 for 70/30 copper nickel iron.

3.10.3 The test pressure is to be maintained for sufficient time to permit proof that the tubes do not weep, leak or undergo a permanent increase in diameter. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test will be accepted.

3.10.4 Where it is proposed to adopt a test pressure other than that determined in 3.10.2, the proposal will be subject to special consideration.

3.10.5 Subject to special approval, an automated eddy current test can be accepted in lieu of the hydraulic test. Discontinuous irregularities on the external and internal surfaces of the tubes are permitted if they are within the agreed dimensional tolerances, with the exception of cracks, which are not permitted.

3.11 Rectification of defects

3.11.1 The repair of defects by welding is not permitted.

3.12 Identification

3.12.1 Tubes are to be clearly marked by the manufacturer in accordance with the requirements of Chapter 1. The following details are to be shown on all materials which have been accepted:

(a) LR or Lloyd's Register.
(b) Manufacturer's name or trade mark.
(c) Grade of material or designation code.
(d) Identification number and/or initials which will enable the full history of the item to be traced.

3.12.2 Identification is to be by rubber stamp or stencils. Hard stamping is not permitted.

3.13 Certification of materials

3.13.1 A manufacturer's certificate validated by LR is to be issued (*see* Ch 1,3.1), giving the following particulars for each casting or batch of castings which has been accepted:

(a) Purchaser's name and order number.
(b) Specification or grade of material.
(c) Description and dimensions.
(d) Cast number and chemical composition.
(e) Mechanical test results.
(f) Results of stress corrosion cracking test, where applicable.
(g) Hydraulic test report.

Equipment for Mooring and Anchoring

Section

■ *Section 1* Anchors

1.1 Scope

1.1.1 This Section makes provision for the manufacture and testing of anchors constructed from cast, forged and fabricated components.

1.1.2 This Section is applicable to the following types of anchor:
(a) Ordinary.
(b) High holding power (HHP).
(c) Super high holding power (SHHP).

1.1.3 In the context of this Section, the reference to swivels refers to those directly attached to the anchor shank in lieu of the conventional 'D' shackle. For other mooring equipment swivels, *see* 2.13.

1.2 Manufacture

1.2.1 All anchors are to be of an approved design.

1.3 Cast steel anchors

1.3.1 Cast steel anchor heads, shanks, shackles and swivels are to be manufactured and tested in accordance with the requirements of Ch 4,1 and Ch 4,2. The Special grade quality is to be used for anchor heads, shanks and shackles.

1.3.2 Special consideration will be given to the use of other grades of steel for the manufacture of swivels.

1.3.3 To confirm the quality of cast anchor components, the Surveyor is to witness drop and hammering tests.

1.3.4 When drop and hammering tests are required, they are to be carried out as follows:
(a) Each anchor, or the components of an anchor made from more than one piece, is to be dropped from a clear height of 4 m onto a steel slab laid on a solid foundation.
(b) Separately cast flukes, shanks and shackles are to be suspended horizontally from a clear height of 4 m before being dropped.
(c) Anchors cast in one piece are to be drop tested twice from a clear height of 4 m. For the first test, the shank and flukes are to be horizontal. For the second test, two steel blocks are to be placed on the slab, arranged so that the middle of each fluke makes contact with the blocks without the crown making contact with the slab, and the orientation of the anchor is to be vertical with the crown nearest the slab.
(d) If the slab is broken by the impact, the test is to be repeated on a new slab.

1.3.5 When hammering tests are required, they are to be carried out after the drop test on each anchor head and shank, which is slung clear of the ground, using a non-metallic sling, and hammered to check the soundness of the component. A hammer of at least 3 kg mass is to be used.

1.3.6 As part of the manufacturer's works approval, consideration may be given to carrying out drop tests in alternative locations to the manufacturer's when the facilities and location are not suitable.

1.3.7 Repair of fractures or unsoundness detected during the drop or hammering tests are not permitted and the component is to be rejected.

1.4 Forged steel anchors

1.4.1 Forged steel anchor pins, swivels, shanks and shackles are to be manufactured and tested in accordance with the requirements of Ch 5,1 and Ch 5,2 carbon and carbon-manganese steel for welded construction. Rolled steel bar may be used provided that the requirements of Ch 5,1.2.9 are met.

1.4.2 Special consideration will be given to other grades of steel for the manufacture of swivels.

1.5 Fabricated steel anchors

1.5.1 Where it is proposed to use plate material for fabricated steel anchors, it is to comply with the requirements of Ch 3,2 or Ch 3,3, and the proposed manufacturing procedure is to be submitted for approval.

1.5.2 Fabricated anchors are to be manufactured in accordance with Chapter 13.

1.5.3 Stress relief is to be carried out as required in the approved welding procedure.

1.6 Rectification

1.6.1 All rectification is to be agreed with the Surveyor.

1.6.2 Rectification of defective castings is to be carried out in accordance with Ch 4,1.9.

1.6.3 Rectification of defective forgings is to be carried out in accordance with Ch 5,1.9.

1.6.4 Rectification of defective fabricated anchors is to be carried out by suitably qualified welders within the parameters of the approved welding procedure used in construction.

1.6.5 Rectification of defective castings, forgings or fabricated anchors by welding is to be carried out using qualified weld procedures in accordance with Ch 12,1 and Ch 12,2, and in accordance with Ch 13,1 and Ch 13,2.

1.7 Super high holding power (SHHP) anchors

1.7.1 The impact test requirements for SHHP anchor shackles are to be in accordance with the requirements for Grade U3 in Table 10.2.1.

1.8 Assembly

1.8.1 Assembly and fitting is to be carried out in accordance with the approved design.

1.8.2 Securing of anchor pins, shackle pins or swivels by welding is to be carried out by suitably qualified welders in accordance with an approved welding procedure.

1.9 Proof test of anchors

1.9.1 Anchors having a mass of 75 kg or more inclusive of stock (56 kg in the case of high holding power anchors) are to be tested in the presence of the Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship or mobile offshore unit is to be registered.

1.9.2 The anchor is to be visually examined before application of the proof test load to ensure that it is free from cracks, notches, inclusions and other surface defects that would impair the performance of the product.

1.9.3 As required by 1.9.1, each anchor is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.1.1 for the appropriate mass of the anchor. The proof load is to be applied on the arm or on the palm at a spot which, measured from the extremity of the bill, is one-third of the distance between it and the centre of the crown. For stocked anchors, each arm is to be tested individually. For stockless anchors, both arms are to be tested at the same time, first on one side of the shank, then reversed and tested on the other.

Table 10.1.1 Proof load tests for anchors
(*see* Notes 1 and 2)

Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN	Mass of anchor (1.6.5) kg	Proof test load kN
50	23,2	2200	376,0	7800	861,0
55	25,2	2300	388,0	8000	877,0
60	27,1	2400	401,0	8200	892,0
65	28,9	2500	414,0	8400	908,0
70	30,7	2600	427,0	8600	922,0
75	32,4	2700	438,0	8800	936,0
80	33,9	2800	450,0	9000	949,0
90	36,3	2900	462,0	9200	961,0
100	39,1	3000	474,0	9400	975,0
120	44,3	3100	484,0	9600	987,0
140	49,0	3200	495,0	9800	998,0
160	53,3	3300	506,0	10 000	1010,0
180	57,4	3400	517,0	10 500	1040,0
200	61,3	3500	528,0	11 000	1070,0
225	65,8	3600	537,0	11 500	1090,0
250	70,4	3700	547,0	12 000	1110,0
275	74,9	3800	557,0	12 500	1130,0
300	79,5	3900	567,0	13 000	1160,0
325	84,1	4000	577,0	13 500	1180,0
350	88,8	4100	586,0	14 000	1210,0
375	93,4	4200	595,0	14 500	1230,0
400	97,9	4300	604,0	15 000	1260,0
425	103,0	4400	613,0	15 500	1280,0
450	107,0	4500	622,0	16 000	1300,0
475	112,0	4600	631,0	16 500	1330,0
500	116,0	4700	638,0	17 000	1360,0
550	125,0	4800	645,0	17 500	1390,0
600	132,0	4900	653,0	18 000	1410,0
650	140,0	5000	661,0	18 500	1440,0
700	149,0	5100	669,0	19 000	1470,0
750	158,0	5200	677,0	19 500	1490,0
800	166,0	5300	685,0	20 000	1520,0
850	175,0	5400	691,0	21 000	1570,0
900	182,0	5500	699,0	22 000	1620,0
950	191,0	5600	706,0	23 000	1670,0
1000	199,0	5700	713,0	24 000	1720,0
1050	208,0	5800	721,0	25 000	1770,0
1100	216,0	5900	728,0	26 000	1800,0
1150	224,0	6000	735,0	27 000	1850,0
1200	231,0	6100	740,0	28 000	1900,0
1250	239,0	6200	747,0	29 000	1940,0
1300	247,0	6300	754,0	30 000	1990,0
1350	255,0	6400	760,0	31 000	2030,0
1400	262,0	6500	767,0	32 000	2070,0
1450	270,0	6600	773,0	34 000	2160,0
1500	278,0	6700	779,0	36 000	2250,0
1600	292,0	6800	786,0	38 000	2330,0
1700	307,0	6900	794,0	40 000	2410,0
1800	321,0	7000	804,0	42 000	2490,0
1900	335,0	7200	818,0	44 000	2570,0
2000	349,0	7400	832,0	46 000	2650,0
2100	362,0	7600	845,0	48 000	2730,0

Proof loads for intermediate mass are to be determined by linear interpolation

NOTES

1. Where ordinary anchors have a mass exceeding 48 000 kg, the proof loads are to be taken as 2,059 (mass of anchor in kg)$^{2/3}$ kN.
2. Where high holding power anchors have a mass exceeding 36 000 kg, the proof loads are to be taken as 2,452 (actual mass of anchor in kg)$^{2/3}$ kN.

1.9.4 The general arrangements for the test are to be such that the complete anchor, including the shackle, shackle pins and any welded or bolted connections are included in the test. If a replacement shackle is needed which requires welding or heating for fitting, the combined anchor and shackle are to be proof load tested. If welding or heating is not involved in fitting, the shackle may be proof load tested separately from the anchor.

1.9.5 The mass to be used in Table 10.1.1 is:

(a) For stockless anchors, the total mass of the anchor.
(b) For stocked anchors, the mass of the anchor excluding the stock.
(c) For high holding power anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor.
(d) For mooring anchors, including positional mooring anchors, a nominal mass equal to 1,33 times the actual total mass of the anchor, unless specifically agreed otherwise.
(e) For super high holding power anchors, a nominal mass equal to twice the actual total mass of the anchor.

1.9.6 For positional mooring anchors, the proof test loading is to be that required by 1.9.3 or 50 per cent of the minimum break strength of the intended anchor line, whichever is the greater.

1.9.7 The gauge length is to be measured with 10 per cent of the required load applied, before and after proof test. The two measurements shall differ by no more than 1 per cent. The gauge length is the distance between the tip of each fluke and a point on the shank adjacent to the shackle pin, *see* Fig. 10.1.1.

1.9.8 After proof testing, all accessible surfaces are to be visually inspected by the Surveyor.

1.9.9 Following proof testing, NDE is to be conducted as described in Table 10.1.2 for ordinary and HHP anchors and Table 10.1.3 for SHHP anchors.

1.9.10 Each casting is to be subjected to ultrasonic inspection in the region of runners and risers, or where excess material has been removed by thermal methods. This examination is to extend around the whole periphery of the casting and for a distance of $t/3$ beyond the area affected, where t is the maximum thickness. In addition, random areas are to be selected by the Surveyor and examined.

1.9.11 Acceptance criteria for castings are to be in accordance with Chapter 4.

1.9.12 Acceptance criteria for forgings are to be in accordance with Chapter 5.

1.9.13 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.1.2 NDE requirements following proof testing for Ordinary and HHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Penetrant testing is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

Table 10.1.3 NDE requirements following proof testing for SHHP anchors

Location	Method of NDE
Feeder heads, runners and risers of castings	Magnetic particle inspection and ultrasonic test, *see* Note 1
All surfaces of castings	Magnetic particle inspection
All welds	Magnetic particle inspection
Forged components	Not required
Fabrication welds	Magnetic particle inspection

NOTES
1. *See also* 1.9.10.
2. Additionally, all surfaces of all SHHP anchors are to be surface inspected by the magnetic particle or penetrant method as appropriate.
3. Penetrant is to be used in lieu of magnetic particle testing for stainless steel, aluminium and copper alloy anchors.

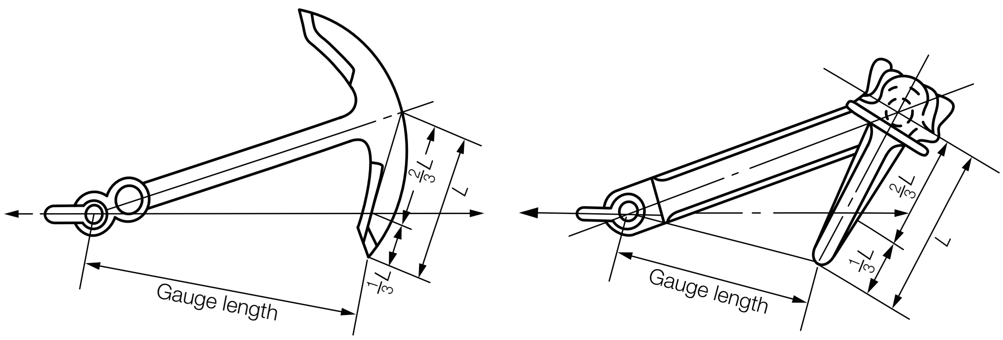


Fig. 10.1.1 Location of gauge length measurement during proof load

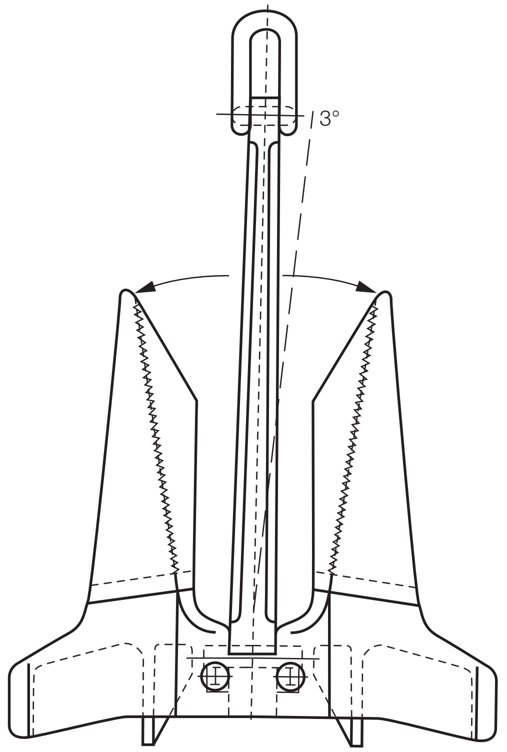


Fig. 10.1.2 Allowable lateral movement of shank

1.9.14 On completion of the proof testing, anchors made in more than one piece are to be examined for free movement of their heads over the complete range of rotation.

1.10 Clearances and tolerances

1.10.1 Where no fitting tolerances are specified on the approved plans the following assembly and fitting tolerance are to be applied.

1.10.2 The clearance either side of the shank within the shackle jaws and the shackle pin in the shank end hole is to be no more than 3 mm for small anchors up to 3 tonnes, 4 mm for anchors up to 5 tonnes, 6 mm for anchors up to 7 tonnes and is not to exceed 12 mm for larger anchors.

1.10.3 The shackle pin is to be a push fit in the eyes of the shackle, which are to be chamfered on the outside to ensure a good tightness when the pin is clenched over on fitting. The shackle pin to hole tolerance is to be no more than 0,5 mm for pins up to 57 mm and 1,0 mm for pins of larger diameter.

1.10.4 The trunnion pin is to be a snug fit within the chamber and be long enough to prevent horizontal movement. The gap is to be no more than 1 per cent of the chamber length.

1.10.5 The lateral movement of the shank is not to exceed 3 degrees from the centreline datum, *see* Fig. 10.1.2.

1.10.6 Unless otherwise agreed, the verification of mass and dimensions is the responsibility of the manufacturer. The Surveyor is only required to monitor this inspection. The mass of the anchor is to exclude the mass of the swivel, unless the swivel is in lieu of the conventional 'D' shackle.

1.11 Identification

1.11.1 Identification marks on the shank are to be approximately level with the fluke tips. On the fluke, these markings are to be approximately at a distance of two thirds from the tip of the bill to the centre line of the crown on the right hand fluke, looking from the crown towards the shank.

1.11.2 The following details are to be shown on all anchors:
(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of the certificate.
(c) Month and year of test.
(d) Mass (also the letters 'HHP' when approved as high holding power anchors or 'SHHP' when approved as super high holding power anchors).
(e) Mass of stock (in the case of stocked anchors).
(f) National Authority requirements, as applicable.
(g) Manufacturer's mark.

1.11.3 In addition to 1.11.2, each important part of an anchor is to be plainly marked by the maker with the words 'forged steel' or 'cast steel' as appropriate. Fabricated steel anchor heads do not require special marking.

1.12 Certification

1.12.1 The manufacturer is to provide the Surveyor with a written statement that the anchor has been manufactured and tested in accordance with LR Rules together with the following particulars:
(a) Purchaser's name and order number.
(b) Type of anchor and principal dimensions.
(c) Mass of anchor.
(d) Identification mark which will enable the full history of manufacture to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Proof load.
(j) Results of the non-destructive examination.
(k) Weld location maps (cast steel anchors only).

1.12.2 Shanks, heads, pins, shackles and swivels are to be certified by LR in accordance with the relevant sections of Chapters 3, 4 and 5.

1.12.3 An LR Anchor Certificate is to be issued for the completed anchor which will include the following particulars:
(a) Manufacturer's name.
(b) Type of anchor.
(c) Mass of anchor.
(d) Grade of materials.
(e) Proof test load.
(f) Heat treatment.
(g) Marking applied to anchor.
(h) Dimensions.
(j) General Approval of an Anchor Design Certificate Number.
(k) Fluke and shank identification numbers.

■ *Section 2* Stud link chain cables for ships

2.1 Scope

2.1.1 Provision is made in this Section for a range of grades, U1, U2 and U3, of stud link chain and fittings intended for anchor or mooring cables for ships.

2.1.2 The requirements for offshore mooring chain cables are given in Section 3.

2.2 Manufacture

2.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers of stud link chain cables and fittings is published separately by LR.

2.2.2 The links may be made by the flash-butt or other approved welding process, or in the case of Grades U2 and U3 they may be flash-butt welded or drop forged, designated U2(a) or U3(a), or cast steel designated U2(b) or U3(b), *see* Table 10.2.5.

2.2.3 As far as practicable, consecutive links in all chain cable should originate from a single cast or batch of bar stock (*see* Ch 3,9.6.1), and indicating marks should be stamped on the final link formed from one cast or batch and the first link formed from a separate cast or batch.

2.2.4 A length of chain cable is to measure not more than 27,5 m and is to comprise an odd number of links. In this context, a length is a statutory term and is the basis for the number of test samples.

2.3 Flash butt welded chain cable

2.3.1 Bar material is to comply with the requirements of Ch 3,9 and may be heated either by electrical resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control. The temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and checks are to be recorded.

2.3.2 Mechanical properties testing of U1 cable is not required. For Grade U2 cable supplied in the as-welded condition, and Grade U3 in all conditions, one tensile and one set of three Charpy V-notch impact test specimens are to be taken at the side of a link opposite the weld from at least every fourth 27,5 m length of cable. A further set of three impact test specimens is to be taken with the notch positioned at the centre of the weld, *see* Table 10.2.3. The test specimens are not to be selected from the same length as that from which the breaking test sample is taken, unless breaking test samples are to be taken from every length of the batch. All test samples are to be correctly identified with the lengths of cable represented.

2.3.3 The test links from which the mechanical test specimens are prepared are to be made as part of the chain cable and are to be heat treated with it. They may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to preparation of the mechanical test specimens.

2.3.4 The results of tests on specimens taken from the non-welded areas are to comply with the appropriate requirements of Table 10.2.1. The results of tests on the welds are to comply with the requirements of Table 10.2.6.

2.4 Cast chain cables

2.4.1 The manufacture of cast steel chain cable is generally to be in accordance with the requirements of Ch 4,1, as appropriate.

2.4.2 The chemical composition of ladle samples is to comply with the specification approved by LR.

2.4.3 Separately cast test samples are to be provided from each cast. They are to be of similar dimensions to the links they represent and are to be heat treated together with, and in the same manner as, the completed chain cable, *see* Table 10.2.3.

2.4.4 Tensile and Charpy V-notch impact test specimens are to be taken from each test sample and machined to the dimensions given in Ch 2,3.

2.4.5 The results of all tests are to comply with the requirements given in Table 10.2.1 for the relevant grade.

2.5 Forged chain cables

2.5.1 The procedure for the manufacture and testing of drop forgings for chain cable will be specially considered, but is generally to be in accordance with the appropriate requirements of Ch 5,1.

2.5.2 The chemical composition is to comply with Table 10.2.2.

2.5.3 The completed forgings are to be heat treated in accordance with Table 10.2.3.

2.5.4 Test samples in the form of forgings of similar dimensions to the links they represent and from the same cast and heat treatment charge are to be provided.

2.5.5 One tensile and three Charpy V-notch specimens are to be taken from each test sample.

2.5.6 The results of mechanical tests are to comply with the requirements of Table 10.2.1 for the relevant grade.

2.6 Stud material

2.6.1 Steel studs are to be used for all grades of welded chain cable. In general, the carbon content should not exceed 0,23 per cent but mechanical tests for acceptance purposes are not required.

2.7 Welding of studs

2.7.1 Where studs are welded into the links this is to be completed before the chain cable is heat treated.

2.7.2 The stud ends must be a good fit inside the link, and the weld is to be confined to the stud end opposite the flash-butt weld. The full periphery of the stud end is to be welded. If, however, it can be demonstrated to the Surveyor that the quality of welding is of a high standard then partial peripheral welding may be accepted provided that welds are made only at the sides of the stud and that each run extends continuously for at least 25 per cent of the stud periphery. Weld start/stop positions are not to be located in the plane of the chain cable.

2.7.3 The welds are to be made by qualified welders using an approved procedure and consumables approved to Grade 3 and low hydrogen, in accordance with Chapter 11.

2.7.4 The welds are to be of good quality and free from defects liable to impair the proper use of the chain. Undercuts, end craters and similar stress raising defects shall, where necessary, be ground off.

2.7.5 At least one stud weld within each length of cable is to be inspected using dye penetrant testing in accordance with Ch 1,5 after the chain has been proof loaded. If a crack is found, the stud welds in the adjoining links are to be inspected; if a crack is found in either link, all the stud welds in that length are to be inspected using dye penetrant.

2.7.6 The size of the stud welds is to be in accordance with Fig. 10.3.1.

2.8 Heat treatment of completed chain cables

2.8.1 The completed chain cable is to be heat treated in accordance with Table 10.2.3 for the appropriate grade of cable.

2.8.2 Special consideration will be given to the heat treatment of certain types of drop forged chain cable.

2.8.3 In all cases, heat treatment is to be carried out prior to the proof loading and breaking tests.

2.8.4 All test samples are to be heat treated with, and in the same way as, the chain cables they represent.

Table 10.2.1 Mechanical properties of finished chain cable and fittings

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation on $5,65\sqrt{S_o}$ % minimum	Reduction of area % minimum	Charpy V-notch impact tests	
					Test temperature °C	Average energy J minimum
U2	295	490 – 690	22	—	0 (*see* Note 1)	27
U3	410	690 minimum	17	40	0 –20 (*see* Note 2)	60 35

NOTES
1. When required *see* Table 10.2.3.
2. Testing may be carried out at either 0°C or –20°C.
3. Mechanical testing is not required for finished chain cables and fittings in Grade U1.

Table 10.2.2 Chemical composition of butt welded and forged chain cable

Grade	Chemical composition %												
	C max.	Si	Mn	P max.	S max.	Al	N max.	Cr max.	Cu max.	Nb max.	Ni max.	V max.	Mo max.
U1	0,20	0,15 – 0,35	0,40 min.	0,04	0,04	—	—	—	—	—	—	—	—
U2	0,24	0,15 – 0,55	1,60 max.	0,035	0,035	0,02 min. *see* Note 1	—	—	—	—	—	—	—
U3	0,33	0,15 – 0,35	1,90 max.	0,04	0,04	0,065 max. *see* Note 2	0,015	0,25	0,35	0,05 *see* Note 2	0,40	0,10 *see* Note 2	0,08

NOTES
1. Aluminium may be partly replaced by other grain refining elements.
2. To obtain fine grain steel, at least one of these grain refining elements must be present in sufficient amount.

Table 10.2.3 Condition of supply and scope of mechanical tests for finished chain cables and fittings

Grade	Manufacturing method	Condition of supply	Number of test specimens on every four lengths of chain cable of 27,5 m or less, or on each batch of fittings		
			Tensile test on base materials	Charpy V-notch impact test	
				Base material	Weldment
U1 cable	Flash butt welded	As welded Normalised	— —	— —	— —
U2 cable	Flash butt welded	As welded Normalised	1 —	3 —	3 —
U3 cable	Flash butt welded	Normalised Normalised and Tempered Quenched and Tempered	1	3	3
U2 cable	Cast or drop forged	Normalised	1	3	—
U3 cable	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—
U2 fittings	Cast or drop forged	Normalised	1	3	—
U3 fittings	Cast or drop forged	Normalised Normalised and Tempered Quenched and Tempered	1	3	—

2.9 Testing of completed chain cables

2.9.1 All chain cables are to be subjected to a Proof Load test and a Breaking Load test. In addition, mechanical tests should be carried out where required, *see* Table 10.2.3.

2.9.2 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published separately by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

2.10 Proof load tests

2.10.1 Each length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable.

2.10.2 On completion of the test, each link is to be visually examined and is to be free from significant defects. Special attention is to be given to welds.

2.10.3 Should any link be found to be defective it is to be replaced by an approved connecting link (joining shackle or substitute link as detailed in 2.14). The chain is then to be subjected to a repeat of the proof load test followed by re-examination.

2.10.4 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 2.10. If either of these samples fails, the length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected.

2.11 Breaking load tests

2.11.1 Breaking load tests are to be carried out on three-link samples selected by the Surveyor from the completed (including heat treatment) chain. The test links may be removed from the chain prior to heat treatment provided that each sample is heat treated with, and in the same manner as the chain it represents. They are to be properly identified with the lengths of chain they represent.

2.11.2 The number of tests required is to be in accordance with Table 10.2.5 except that for chafing chain for Emergency Towing Arrangements (ETA), *see* Pt 3, Ch 13,10.2, one test is to be carried out on each 110 m of finished chains.

2.11.3 Breaking test specimens are to withstand the load given in Table 10.2.4 for the appropriate grade and size of cable. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load for a minimum of 30 seconds.

2.11.4 Where a breaking test specimen fails, a further specimen is to be cut from the same length of cable and subjected to test. If this re-test fails, the length of cable from which it was taken is to be rejected. When this test is also representative of other lengths, each of the remaining lengths is to be individually tested by taking a breaking test specimen from each length of the batch. If one of these further tests fails, the entire set of lengths represented by the original test is to be rejected.

2.11.5 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

2.12 Dimensional inspection

2.12.1 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

2.12.2 The links held in the end blocks may be excluded from these measurements.

2.12.3 If a five link length of chain exceeds the tolerance given in 2.15.5, then the oversize links are to be removed and an approved connecting link inserted.

2.12.4 Checks of all other dimensions are to be made on three links, selected by the Surveyor, from every four 27,5 m lengths.

2.12.5 If one of the links detailed in 2.12.4 fails to comply with the required tolerances, measurements are to be made on a further five links in every four 27,5 m lengths.

2.12.6 If more than one link in a 27,5 m length of chain cable fails to meet the tolerance requirements, all the links in that length are to be measured.

2.12.7 All links failing to comply with the maximum dimensional tolerances are to be removed and replaced by connecting links of an approved type. The chain is then to be subjected to a further proof load test and re-examined.

2.12.8 If the length over five links is less than the nominal, then the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and only random lengths of the chain need to be stretched.

2.12.9 Loads used for plastic straining to set studs are not to exceed 0,8 per cent of the proof load unless specifically approved for higher loads.

2.12.10 Paint or anti-corrosive coatings are not to be applied until these inspections are completed to the satisfaction of the Surveyor.

Table 10.2.4 Test loads for stud link anchor chain cables

Chain diameter	Grade U1		Grade U2		Grade U3	
	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN	Proof load kN	Breaking load kN
d mm	$0,00686d^2$ $(44-0,08d)$	$0,00981d^2$ $(44-0,08d)$	$0,00981d^2$ $(44-0,08d)$	$0,01373d^2$ $(44-0,08d)$	$0,01373d^2$ $(44-0,08d)$	$0,01961d^2$ $(44-0,08d)$
12,5	46	66	66	92	—	—
14	58	82	82	115	—	—
16	75	107	107	150	—	—
17,5	89	128	128	179	—	—
19	105	150	150	211	—	—
20,5	122	175	175	244	244	349
22	140	201	201	281	281	401
24	166	238	238	333	333	475
26	194	278	278	389	389	556
28	225	321	321	450	450	642
30	257	367	367	514	514	734
32	291	416	416	583	583	832
34	327	468	468	655	655	936
36	366	523	523	732	732	1045
38	406	580	580	812	812	1160
40	448	640	640	896	896	1280
42	492	703	703	984	984	1406
44	538	769	769	1076	1076	1537
46	585	837	837	1171	1171	1673
48	635	908	908	1270	1270	1814
50	686	981	981	1373	1373	1961
52	739	1057	1057	1479	1479	2113
54	794	1135	1135	1589	1589	2269
56	850	1216	1216	1702	1702	2430
58	908	1299	1299	1818	1818	2597
60	968	1384	1384	1938	1938	2767
62	1029	1472	1472	2060	2060	2943
64	1092	1562	1562	2187	2187	3123
66	1157	1655	1655	2316	2316	3308
68	1223	1749	1749	2448	2448	3496
70	1291	1846	1846	2583	2583	3690
73	1395	1995	1995	2792	2792	3988
76	1503	2149	2149	3007	3007	4295
78	1576	2254	2254	3154	3154	4505
81	1689	2415	2415	3380	3380	4827
84	1805	2580	2580	3612	3612	5158
87	1923	2750	2750	3849	3849	5498
90	2045	2924	2924	4093	4093	5845
92	2127	3042	3042	4258	4258	6081
95	2254	3223	3223	4510	4510	6442
97	2339	3345	3345	4682	4682	6687
100	2470	3532	3532	4943	4943	7060
102	2558	3658	3658	5120	5120	7312
105	2692	3850	3850	5389	5389	7697
107	2783	3980	3980	5571	5571	7957
111	2968	4245	4245	5941	5941	8486
114	3110	4447	4447	6224	6224	8889
117	3253	4652	4652	6511	6511	9299
120	3398	4859	4859	6801	6801	9714
122	3496	4999	4999	6997	6997	9994
124	3595	5141	5141	7195	7195	10276
127	3744	5354	5354	7494	7494	10703
130	3895	5571	5571	7796	7796	11135
132	3997	5716	5716	8000	8000	11426
137	4254	6083	6083	8514	8514	12161
142	4515	6456	6456	9036	9036	12906
147	4779	6834	6834	9565	9565	13662
152	5046	7217	7217	10100	10100	14426
157	5316	7602	7602	10640	10640	15197
162	5588	7991	7991	11185	11185	15975

Table 10.2.5 Number of breaking tests from completed cables

Designation	Method of manufacture	Number of breaking test specimens
Grade U1	Flash-butt welded and heat treated	One from every four lengths of 27,5 m or less
Grade U2(a) U3(a)	Flash-butt welded, or drop forged and heat treated	One from every four lengths of 27,5 m or less
Grade U1 U2(a)	Flash-butt welded but not heat treated	One from each length of 27,5 m or less
Grade U2(b) U3(b)	Cast and heat treated	One per heat treatment batch with a minimum of one from every four lengths of 27,5 m or less

Table 10.2.6 Mechanical properties of welds in chain cables

Grade	Charpy V-notch impact test	
	Test temperature °C	Average energy J min
U1	—	—
U2	0 (*see* Note 1)	27
U3	0	50
	–20 (*see* Note 2)	27

NOTES
1. Impact tests are only required if the chain cable is not heat treated.
2. Impact testing may be carried out at 0°C or minus 20°C.

2.13 Fittings for chain cables

2.13.1 Cable fittings are to be manufactured at an approved works.

2.13.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1 respectively. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

2.13.3 All fittings are to be manufactured to an approved manufacturing specification, and provision is to be made for tensile specimens and, where applicable, impact test specimens, *see* Table 10.2.3. The test samples are to be prepared in accordance with 2.4.3 or 2.5.4 as applicable. The test specimens are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.2.1. A batch of fittings is to be of the same grade, size and heat treatment charge and to have originated from a single cast of steel. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable. Mechanical tests of pins are to be taken in accordance with 3.8.15.

2.13.4 Fittings such as shackles, swivels and swivel shackles are to be forged or cast in steel of at least Grade U2. The welded construction of fittings may also be approved providing that full details of the manufacturing process and the heat treatment are submitted.

2.13.5 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended. These include shackles, swivels, swivel shackles, enlarged links and end links. Anchor shackles, however, are to be tested in combination with the anchor, *see* 1.4.

2.13.6 The appropriate breaking load is to be applied for a minimum of 30 seconds to at least one item out of every batch of up to 25 (1 in 50 for lugless (Kenter) shackles), and this item is to be destroyed and not used as part of an outfit. For the purpose of break load testing, a batch of accessories is to be of the same grade, size and heat treatment charge and may consist of items from different casts, provided that the sample tested is from the cast with the lowest tensile properties. Enlarged and end links need not be tested provided that they are manufactured and heat treated together with the chain cable.

2.13.7 If the sample fails to withstand the breaking load without fracture, two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

2.13.8 Where the items are of increased dimensions, and have been specially approved, or if material of a higher grade than is specified is used, then the breaking load is to be applied to each item, and the items so tested included with the outfit. For the purpose of this paragraph, items of increased dimensions are those so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load of the chain cable with which they are to be used.

2.13.9 LR may waive the breaking load test provided that:
(a) the breaking load test has been completed satisfactorily during approval testing, and
(b) the tensile and impact properties of each manufacturing batch are proved and
(c) the accessories are subjected to suitable non-destructive testing.

2.13.10 All testing is to be carried out in the presence of the Surveyor and to his satisfaction.

2.13.11 All fittings are to be stamped in accordance with 2.16.

2.14 Substitute single links

2.14.1 Single links to connect lengths of chain cable or to substitute for defective links, without the necessity for re-heat treatment of the whole cable length, are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and the tests are to be made on the maximum size of chain for which approval is sought. Re-approval is required annually.

2.14.2 Manufacture and heat treatment of the substitute link are not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

2.14.3 The steel bar used is to conform with the specification for the chain in accordance with Ch 3,9.

2.14.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

2.14.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

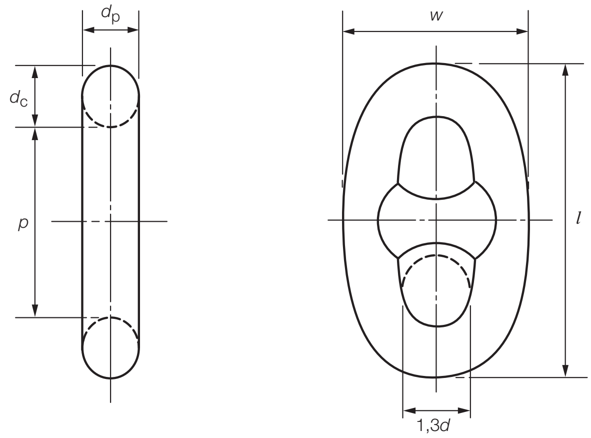
2.14.6 Every substitute link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated, as detailed in Table 10.2.4.

2.14.7 Each substitute link is to be stamped on the stud with the identification marks listed in 2.16.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

2.15 Dimensions and tolerances

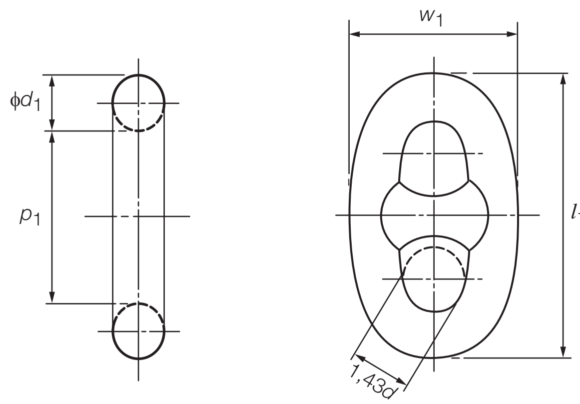
2.15.1 The form and proportion of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a standard recognised by LR, such as ISO 1704; alternatively the design may be specifically approved by LR.

2.15.2 Manufacturing tolerances on stud link chain are to be within ±2,5 per cent (taking into account that all components of the chain are to be a good fit with one another), except for those detailed in 2.15.3.



d_c = nominal diameter at crown measured in plane of link
d_p = nominal diameter at crown measured perpendicular to plane of link
l = 6d
p = 4d
w = 3,6d to the nearest millimetre

Fig. 10.2.1 Common link



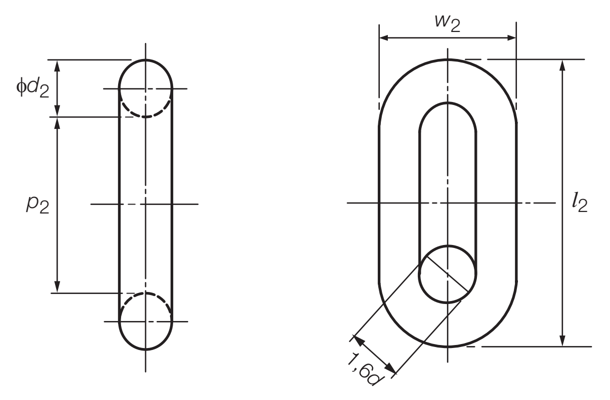
d = nominal diameter of common stud link
d_1 = nominal diameter of enlarged stud link = 1,1d
l_1 = $6d_1 \approx 6{,}6d$
p_1 = $4d_1 \approx 4{,}4d$
w_1 = $3{,}6d_1 \approx 3{,}96d$

Fig. 10.2.2 Enlarged link

2.15.3 The nominal diameter, d, is to be the average of the diameters, measured in the plane of the link, d_c, and perpendicular to the plane of the link, d_p, *see* Fig. 10.2.1. The negative tolerance on the nominal diameter is not to exceed the following:

Minus 1 mm when $d \le 40$ mm
Minus 2 mm when 40 mm $< d \le 84$ mm
Minus 3 mm when 84 mm $< d \le 122$ mm
Minus 4 mm when $d > 122$ mm

The plus tolerance on the diameter at the crown measured out of the plane of the link, d_p, is not to exceed 5 per cent.



d = nominal diameter of common stud link
d_2 = nominal diameter of end link = 1,2d (d_2 – 1,2d)
l_2 = $p_2 + 2d_2 \approx 6{,}75d$
p_2 = $3{,}65d_2 \approx 4{,}35d$
w_2 = $3{,}3d_2 \approx 4d$

Fig. 10.2.3 End link

2.15.4 The cross-sectional area is to be calculated using the nominal diameter, *d*. The cross-sectional area at the crown of the link is to have no negative tolerance.

2.15.5 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 of Chapter 3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

2.15.6 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is plus 2,5 per cent. No under-tolerance is permitted.

2.15.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

2.15.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. Tolerances in accordance with Fig. 10.3.1 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

2.15.9 The following tolerances are applicable to accessories:

Nominal diameter: plus 5 per cent, minus 0 per cent
Other dimensions: ±2,5 per cent.

2.15.10 For lugless shackles of the Kenter type, the radii indicated in Fig. 10.2.8 are to be not less than 0,03 times the chain diameter.

2.15.11 All materials are to be free from internal and surface defects that might impair proper workability, use and strength. Subject to agreement by the Surveyor, surface defects may be removed by grinding provided the acceptable tolerances are not exceeded.

2.16 Identification

2.16.1 All lengths of Grades U1, U2 and U3 cable and all fittings are to be stamped with the following identification marks:

(a) LR or Lloyd's Register and abbreviated name of LR's local office issuing the certificate.
(b) Number of certificate.
(c) Proof load and grade of chain.
(d) Surveyor's personal stamp.
(e) Each length of chain cable is to be stamped on both ends.

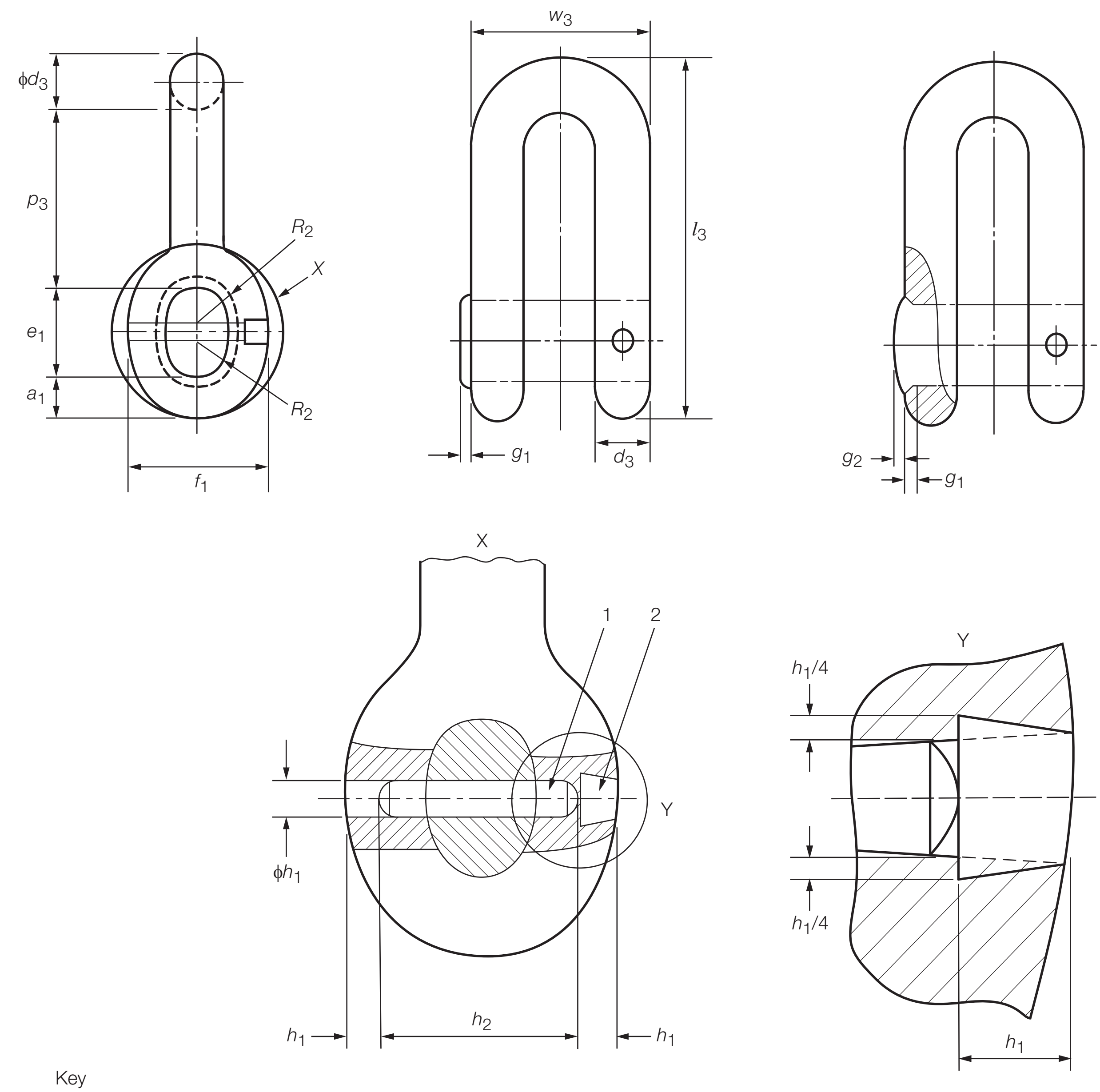
2.17 Certification

2.17.1 An LR certificate is to be issued for chain cable only, fittings only or chain cable with associated fittings.

2.17.2 Each test certificate is to include the following particulars for all items included on the certificate:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain or fitting to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.

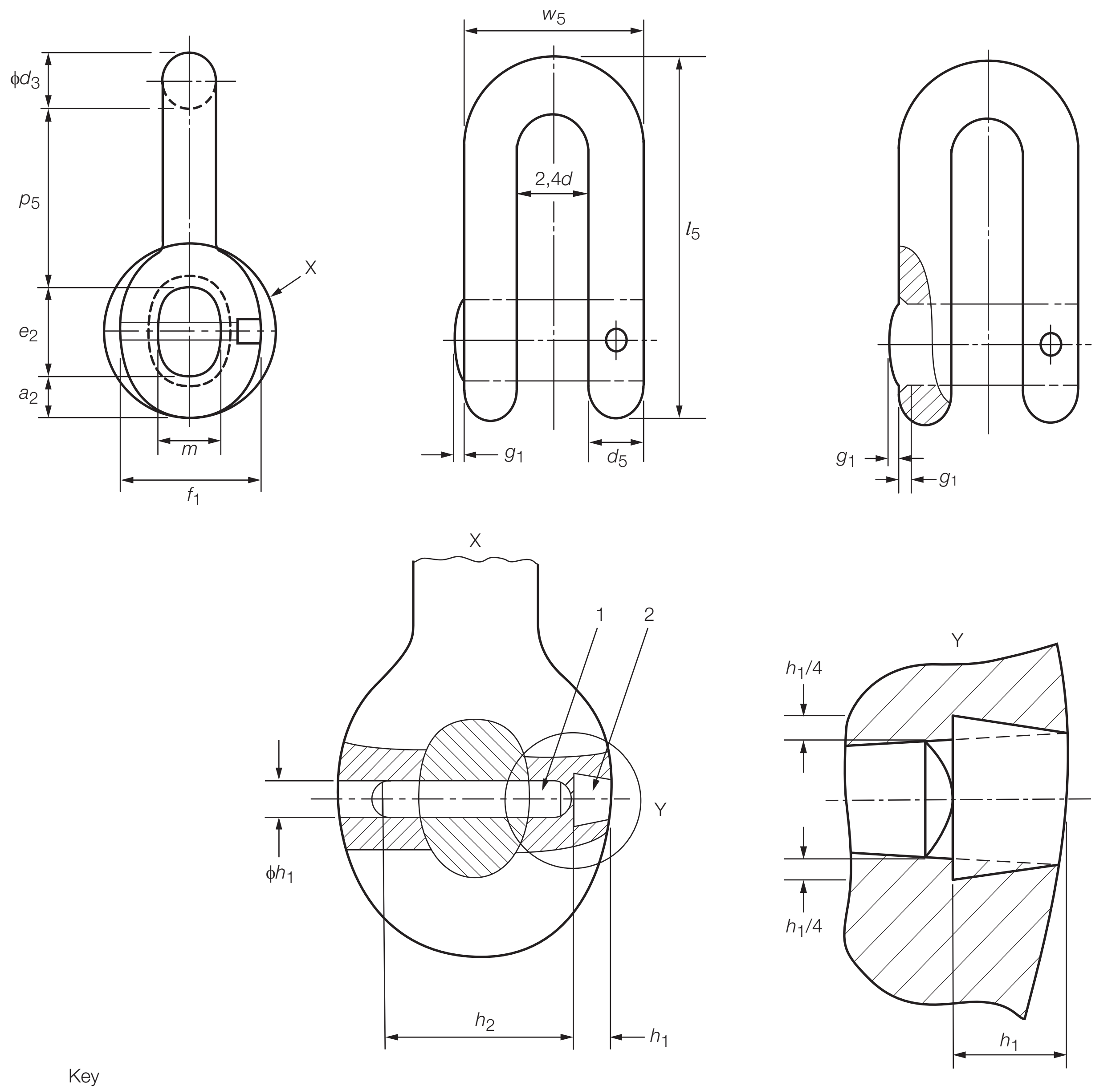
2.17.3 Where appropriate, the certificate is to include a list of all substitute links together with their grade of steel, the name of the steelmaker, the heat number and the purchase order number.



Key
X retaining pin
Y dovetail chamber

d = nominal diameter of common stud link
d_3 = nominal diameter of joining shackle = 1,3d
l_3 = 7,1d
p_3 = $l_3 - (d_3 + a_1 + e_1)$ = 3,4d
w_3 = 4d
a_1 = 0,8d
e_1 = 1,6d
f_1 = 2,8d
g_1 = 0,2d
g_2 = 0,1d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
R_1 = 0,6d
R_2 = 0,5d

Fig. 10.2.4 End shackle

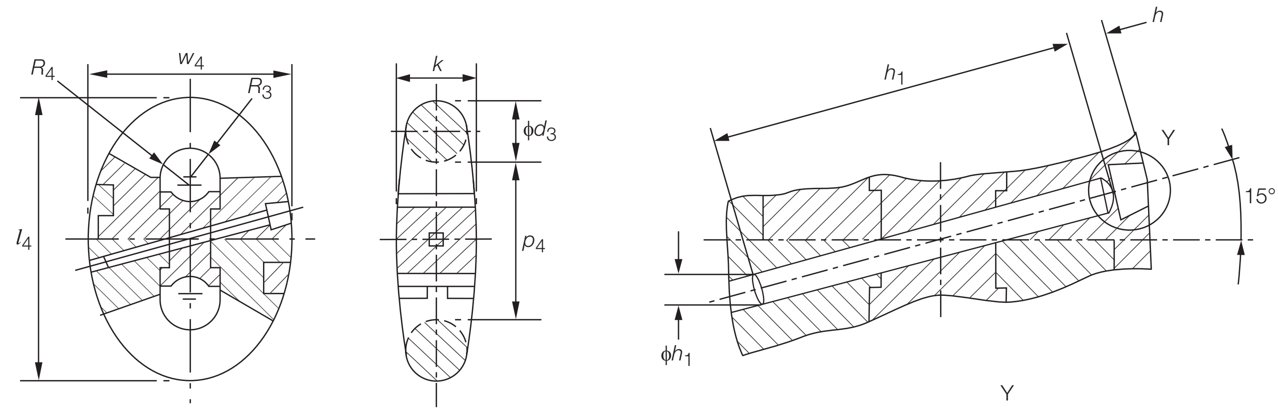


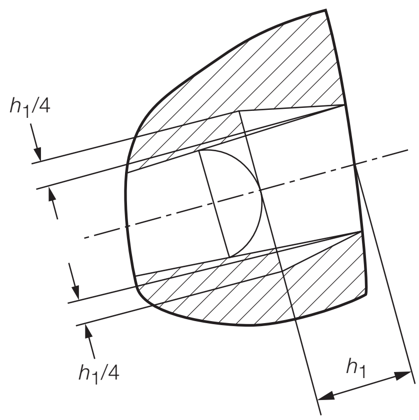
Key
X retaining pin
Y dovetail chamber

d = nominal diameter of common stud link
d_5 = nominal diameter of end shackle = 1,4d
l_5 = 8,7d
p_5 = $l_5 - (d_3 + a_2 + e_2)$ = 4,5d
w_5 = 5,2d
a_2 = 0,9d
e_2 = 1,8d

f_2 = 3,1d
g_1 = 0,2d
g_2 = 0,1d
m = 1,4d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin

Fig. 10.2.5 Dee shackle

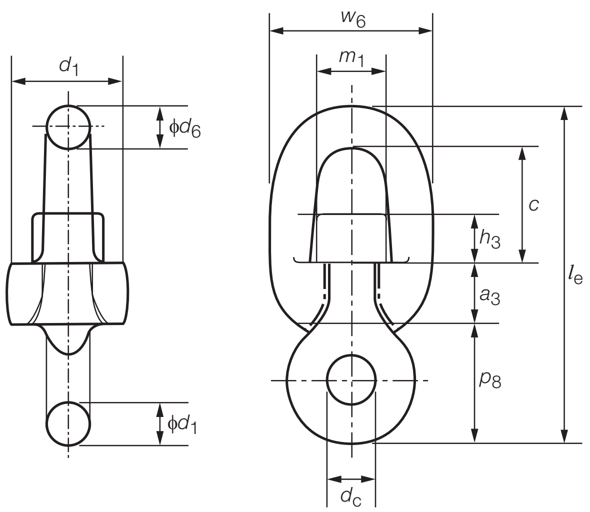




Key
Y = dovetail chamber

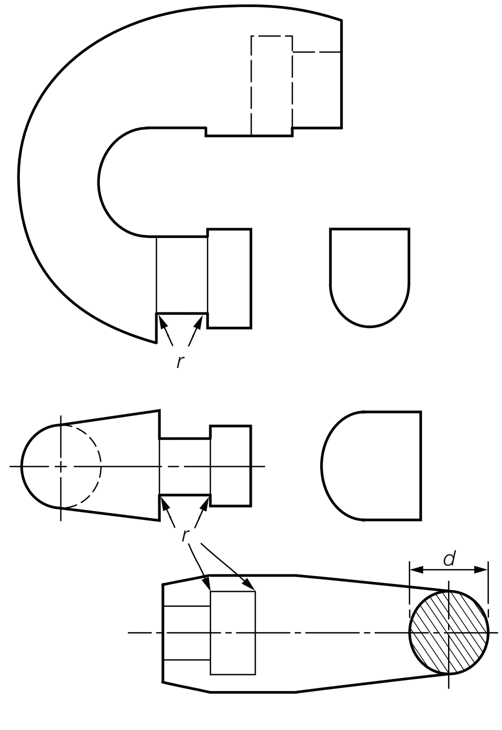
d = nominal diameter of common stud link
d_1 = nominal diameter of Kenter type joining shackle = d
l_4 = 6d
p_4 = 4d
w_4 = 4,2d
h_1 = nominal diameter of taper pin
h_2 = nominal length of taper pin
k = 1,52d
R_3 = 0,67d
R_4 = 1,83d

Fig. 10.2.6 Lugless shackle



d = nominal diameter of common stud link
d_6 = nominal diameter of swivel = 1,2d
l_e = 9,7d
p_e = d_g – 3,4d
w_6 = 4,7d
d_7 = 1,1d
a_3 = 1,76d
m_1 = 2d
h_3 = d_g – 1,4d
c = 3,35d

Fig. 10.2.7 Swivel



The radii indicated by r are to be not less than 0,03 x d

Fig. 10.2.8 Lugless shackle of the Kenter type

■ *Section 3* Stud link mooring chain cables

3.1 Scope

3.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5, of stud link chain intended for offshore mooring applications such as mooring of mobile offshore units, offshore loading systems and gravity based structures during fabrication.

3.1.2 In addition, chain cable conforming to the requirements of the current edition of API specification 2F is acceptable provided that it has been manufactured, inspected and tested under Survey by LR, and that the bar stock has also been certified by LR in accordance with Ch 3,9.

3.2 Manufacture

3.2.1 All grades of chain cable and accessories are to be manufactured by approved procedures at works approved by LR. A list of approved manufacturers for stud link chain cables is published separately by LR.

3.2.2 The works in which the chain is manufactured is to have a quality system approved by LR. The provision of such a quality system is required in addition to and not in lieu of the witnessing of tests by a Surveyor.

3.2.3 Approval is confined to a single works and is limited to one grade of cable made from bar from a nominated and approved supplier. Separate approvals are required if steel bar is supplied from more than one works and for other grades of cable, *see also* Ch 3,9.

3.2.4 Details of the method of manufacture and the specification of the steel, are to be submitted.

3.2.5 Offshore mooring chains are to be made in continuous lengths by flash-butt welding.

3.2.6 Bar material may be heated either by electric resistance or in a furnace. For electrical resistance heating, the process is to be controlled by an optical heat sensor. For furnace heating, thermocouples in close proximity to the bars are to be used for control and the temperature is to be continuously recorded. In both cases, the controls are to be checked at least once every eight hours and records taken.

3.2.7 The following welding parameters (as approved in the weld procedure) are to be controlled during welding of each link:

(a) platen motion;
(b) current as a function of time; and
(c) hydraulic pressure.

The controls are to be checked at least once every four hours.

3.2.8 The records of bar heating, flash-butt welding and heat treatment are to be made available to the Surveyor when required.

3.2.9 As far as practicable, consecutive links in all chain cable should originate from a single batch of bar stock (*see* Ch 3,9.6.1) and indicating marks should be stamped on the final link formed from one batch and the first link formed from a separate batch.

3.3 Dimensions and tolerances

3.3.1 The form and proportions of links and shackles are to be in accordance with ISO/1704-2008, *see* Figs. 10.2.1 to 10.2.8. Design of chain cables must be to a recognised standard, such as ISO 1704; alternatively the design may be specifically approved by LR. Link tolerances are to be in accordance with 3.3.2 to 3.3.6.

3.3.2 Diameter measured at the crown:

Minus 1 mm when $d_c \le 40$ mm
Minus 2 mm when 40 mm < $d_c \le 84$ mm
Minus 3 mm when 84 mm < $d_c \le 122$ mm
Minus 4 mm when 122 mm < $d_c \le 152$ mm
Minus 6 mm when 152 mm < $d_c \le 184$ mm
Minus 7,5 mm when 184 mm < $d_c \le 210$ mm

The plus tolerance must not exceed 5 per cent of the nominal diameter, and the cross-sectional area at the crown is to have no negative tolerance.

3.3.3 The diameter measured at locations other than the crown is to have no negative tolerance. The plus tolerance is to be in accordance with Table 3.9.3 except at the butt weld where it is to be in accordance with the manufacturer's specification, which is to be agreed by LR.

3.3.4 The maximum allowable tolerance on a length of five links measured in accordance with 2.12.1 is +2,5 per cent. No under-tolerance is permitted.

3.3.5 A manufacturing tolerance on all other dimensions of ±2,5 per cent is acceptable subject to all parts fitting properly together.

3.3.6 The tolerances for common links are to be measured in accordance with Fig. 10.3.3.

3.3.7 All measurements are to be made on links selected by the Surveyor and are to be carried out to the Surveyor's satisfaction.

3.3.8 Studs are to be located in the links centrally, and at right angles to the sides of the link, although the studs of the final link at each end of any length may also be located off-centre to facilitate the insertion of the joining shackle. The tolerances in accordance with Fig. 10.3.2 are acceptable provided that the stud fits snugly and its ends lie flush against the inside of the link.

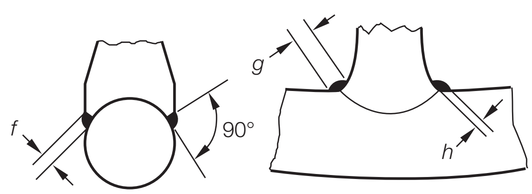
3.4 Studs

3.4.1 The studs are to be made of steel corresponding to that of the chain or in compliance with a specification approved by LR. In general, the carbon content should not exceed 0,23 per cent if the studs are to be welded in place.

3.4.2 Studs may be welded into grade R3 and R3S chains. The welding of studs into grade R4, R4S and R5 chain is not permitted unless specially approved.

3.4.3 In all cases where studs are welded into links, this is to be carried out in accordance with 2.7.

3.4.4 The size of the stud welds is to be in accordance with Fig. 10.3.1.



Dimension Designation	Nominal Dimension	Minus Tolerance
f	0,10*d*	0,01*d*
g	0,20*d*	0,02*d*
h	0,09*d*	0,01*d*

d = Nominal diameter of barstock

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Fig. 10.3.1
Dimensions and tolerances of stud welds

3.4.5 All stud welds are to be visually inspected. At least 10 per cent of all stud welds within each length of chain are to be examined by magnetic particle inspection after proof load testing. Stress raising defects such as cracks, lack of fusion, gross porosity, and undercuts exceeding 1 mm are not permitted; if any such defects are found, then all stud welds in that length of chain are to be examined by means of magnetic particle inspection.

3.4.6 Where plastic straining is used to set studs, the applied load is not to be greater than that qualified in approval tests. The combined effect of shape and depth of the impression of the stud in the link is not to cause any harmful notch effect or stress concentration.

3.5 Heat treatment of completed chain cables

3.5.1 The chain is to be normalised, normalised and tempered or quenched and tempered in accordance with the specification approved by LR.

3.5.2 The chains are to be heat treated in a continuous furnace; batch heat treatment is not permitted.

3.5.3 The temperature and time, or temperature and chain speed, are to be controlled and continuously recorded.

3.5.4 Heat treatment is to be carried out prior to the proof loading and breaking tests.

3.5.5 Calibration of furnaces is to be verified by measurement and recording of actual link temperature (surface and internal).

3.6 Testing of completed chain cables

3.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

3.6.2 The entire length of chain cable is to be subjected to a proof loading test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable.

3.6.3 Care should be taken to obtain a uniform stress distribution in the links being tested.

3.6.4 The chain is to be shot or sand blasted prior to testing in order to ensure that its surfaces are free from scale, paint or other coating for inspection.

3.6.5 On completion of the proof load test, each link is to be visually examined and is to be free from significant defects such as mill defects, surface cracks, dents and cuts, especially where gripped by clamping dies during flash butt welding. Studs are to be securely fastened and any burrs, irregularities and rough edges are to be removed by careful grinding.

3.6.6 All flash butt welds, including the area gripped by the clamping dies, are to be examined by magnetic particle inspection. The area is to be free from cracks, lack of fusion, gross porosity and any other stress concentrations.

3.6.7 Surface defects in the region of the flash butt welds may be removed by grinding, provided that the depth of grinding does not exceed five per cent of the link diameter and is smoothly contoured into the surrounding material. The final dimensions are still to conform with the agreed standard.

3.6.8 All flash butt welds are also to be examined by ultrasonic inspection and are to be free from defects such as internal cracks or lack of fusion.

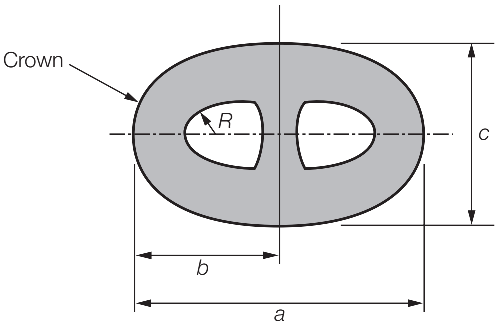
3.6.9 All non-destructive examination is to be carried out in accordance with approved procedures, in accordance with Ch 1,5.

3.6.10 All non-destructive examination operators are to be qualified to a minimum Level II, qualified in accordance with a recognised standard.

3.6.11 After proof testing, the entire chain is to be checked for length, five links at a time with an overlap of two links, which is to include the first five links, to ensure that the chain meets the tolerances given in 2.15.5. The measurements are to be made while the chain is loaded to about 10 per cent of the proof load.

Fig. 10.3.2 Stud link tolerances

The internal link radii (*R*) and external radii should be uniform



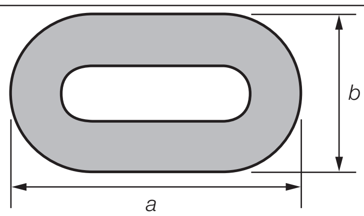
Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link half length	*a**/2	0,10*d*	0,10*d*
c	Link width	3,6*d*	0,09*d*	0,09*d*
e	Stud angular misalignment	0 degrees	4 degrees	4 degrees
R	Inner radius	0,65*d*	0	—

Symbols

d = nominal diameter of chain
*a** = actual link length

Fig. 10.3.3 Studless and common link tolerances

The internal link radii (*R*) and external radii should be uniform



Designation	Description	Nominal dimension of the link	Minus tolerance	Plus tolerance
a	Link length	6*d*	0,15*d*	0,15*d*
b	Link width	3,35*d*	0,09*d*	0,09*d*
R	Inner radius	0,60*d*	0	—

Symbols

d = nominal diameter of chain

NOTE
Other dimensional ratios are subject to special approval.

Table 10.3.1 Test loads for mooring chain cables *(continued)*

Nominal diameter *d*	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
50	1480	1480	2230	1800	1740	2490	2160	1920	2740	2400	2130	3040	2510	2230	3200
52	1594	1594	2402	1939	1874	2682	2327	2068	2952	2585	2295	3275	2704	2402	3447
54	1712	1712	2580	2083	2013	2881	2499	2222	3170	2777	2465	3517	2904	2580	3703
56	1834	1834	2764	2231	2156	3086	2677	2380	3396	2974	2640	3768	3111	2764	3966
58	1960	1960	2953	2383	2304	3297	2860	2542	3628	3178	2820	4025	3323	2953	4237
60	2089	2089	3147	2540	2455	3514	3048	2710	3867	3387	3006	4290	3542	3147	4516
62	2221	2221	3347	2701	2611	3737	3242	2881	4112	3602	3196	4562	3767	3347	4802
64	2357	2357	3551	2867	2771	3965	3440	3058	4364	3822	3392	4841	3997	3551	5096
66	2496	2496	3761	3036	2935	4200	3643	3238	4621	4048	3593	5127	4233	3761	5397
68	2639	2639	3976	3209	3102	4440	3851	3423	4885	4279	3798	5420	4475	3976	5706
70	2785	2785	4196	3387	3274	4685	4064	3613	5156	4516	4008	5720	4723	4196	6021
73	3010	3010	4535	3660	3538	5064	4392	3904	5572	4881	4331	6182	5104	4535	6507
76	3242	3242	4884	3942	3811	5454	4731	4205	6001	5257	4665	6658	5498	4884	7009
78	3400	3400	5123	4135	3997	5720	4962	4411	6295	5514	4893	6984	5766	5123	7351
81	3643	3643	5490	4431	4283	6130	5317	4726	6745	5908	5243	7484	6179	5490	7877
84	3893	3893	5866	4735	4577	6550	5682	5051	7208	6313	5603	7997	6602	5866	8418
87	4149	4149	6252	5046	4878	6981	6056	5383	7682	6729	5972	8523	7037	6252	8971
90	4412	4412	6647	5365	5187	7422	6439	5723	8167	7154	6349	9062	7482	6647	9539
92	4590	4590	6916	5582	5396	7722	6699	5954	8497	7443	6606	9428	7784	6916	9924
95	4862	4862	7326	5913	5716	8180	7096	6307	9001	7884	6997	9987	8246	7326	10512
97	5047	5047	7604	6138	5933	8490	7365	6547	9343	8184	7263	10366	8559	7604	10911
100	5328	5328	8028	6480	6264	8964	7776	6912	9864	8640	7668	10944	9036	8028	11520
102	5519	5519	8315	6712	6488	9285	8054	7159	10217	8949	7942	11336	9359	8315	11932
105	5809	5809	8753	7065	6829	9773	8478	7536	10754	9420	8360	11932	9851	8753	12560
107	6005	6005	9048	7304	7060	10103	8764	7790	11118	9738	8643	12335	10184	9048	12984
111	6404	6404	9650	7789	7529	10775	9347	8308	11856	10385	9217	13154	10861	9650	13847
114	6709	6709	10109	8159	7887	11287	9791	8703	12420	10879	9655	13780	11378	10109	14506
117	7018	7018	10574	8535	8251	11807	10242	9104	12993	11380	10100	14415	11902	10574	15174
120	7331	7331	11047	8916	8619	12334	10700	9511	13573	11889	10551	15059	12434	11047	15852
122	7542	7542	11365	9173	8868	12690	11008	9785	13964	12231	10855	15493	12792	11365	16308
124	7755	7755	11686	9432	9118	13048	11319	10061	14358	12576	11161	15930	13153	11686	16768
127	8078	8078	12171	9824	9497	13591	11789	10479	14955	13099	11626	16592	13700	12171	17466
130	8404	8404	12663	10221	9880	14139	12265	10903	15559	13628	12095	17262	14253	12663	18171
132	8623	8623	12993	10488	10138	14508	12585	11187	15965	13984	12411	17713	14625	12993	18645
137	9178	9178	13829	11162	10790	15441	13395	11906	16992	14883	13209	18852	15565	13829	19844

Table 10.3.1 Test loads for mooring chain cables *(conclusion)*

Nominal diameter d	Grade R3			Grade R3S			Grade R4			Grade R4S			Grade R5		
	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load	Proof test load		Break test load
	Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain		Stud link chain	Studless chain	
mm	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN	kN
142	9741	9741	14677	11847	11452	16388	14216	12637	18033	15796	14019	20008	16520	14677	21061
147	10311	10311	15536	12540	12122	17347	15048	13376	19089	16720	14839	21179	17487	15536	22294
152	10887	10887	16405	13241	12800	18317	15890	14124	20156	17655	15669	22363	18464	16405	23540
157	11469	11469	17282	13949	13484	19297	16739	14879	21234	18599	16507	23559	19452	17282	24799
162	12056	12056	18166	14663	14174	20284	17596	15641	22320	19551	17351	24764	20447	18166	26068
167	12647	12647	19056	15381	14869	21278	18458	16407	23414	20508	18201	25977	21448	19056	27345
172	13240	13240	19950	16103	15566	22276	19324	17177	24513	21471	19055	27196	22455	19950	28628
177	13836	13836	20847	16827	16267	23278	20193	17949	25615	22437	19912	28420	23465	20847	29915
182	14433	14433	21746	17553	16968	24282	21064	18723	26720	23404	20771	29645	24477	21746	31205
187	15029	15029	22646	18279	17670	25286	21935	19498	27825	24372	21630	30871	25489	22646	32496
192	15626	15626	23544	19004	18371	26289	22805	20271	28929	25339	22488	32096	26500	23544	33785
197	16220	16220	24440	19727	19070	27290	23673	21043	30029	26303	23344	33317	27509	24440	35071
202	16813	16813	25332	20448	19766	28286	24537	21811	31126	27264	24196	34534	28513	25332	36351
207	17401	17401	26220	21164	20459	29277	25397	22575	32216	28219	25044	35744	29512	26220	37625
210	17753	17753	26749	21591	20872	29868	25910	23031	32867	28788	25550	36465	30108	26749	38385

Grade R3		
Proof test load	Stud link chain	$0{,}0148d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0148d^2 (44 - 0{,}08d)$
Break test load		$0{,}0223d^2 (44 - 0{,}08d)$
Grade R3S		
Proof test load	Stud link chain	$0.0180d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0174d^2 (44 - 0{,}08d)$
Break test load		$0{,}0249d^2 (44 - 0{,}08d)$
Grade R4		
Proof test load	Stud link chain	$0{,}0216d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0192d^2 (44 - 0{,}08d)$
Break test load		$0{,}0274d^2 (44 - 0{,}08d)$
Grade R4S		
Proof test load	Stud link chain	$0{,}0240d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0213d^2 (44 - 0{,}08d)$
Break test load		$0{,}0304d^2 (44 - 0{,}08d)$
Grade R5		
Proof test load	Stud link chain	$0{,}0251d^2 (44 - 0{,}08d)$
	Studless chain	$0{,}0223d^2 (44 - 0{,}08d)$
Break test load		$0{,}0320d^2 (44 - 0{,}08d)$

3.6.12 The links held in the end blocks may be excluded from these measurements.

3.6.13 If the length over five links is less than the nominal, the chain may be stretched by loading above the specified proof test load provided that the applied load is not greater than ten per cent above the proof test load, and that only random lengths of the chain need to be stretched.

3.6.14 Loads used for plastic straining to set studs are not to exceed those approved in qualification tests.

3.6.15 Checks of all other dimensions are to be made on at least five per cent of the links in the cable.

3.6.16 If any link fails to meet the dimensional tolerance requirements (*see* 3.3), measurements are to be made on 20 more links on each side of the incorrect one. If failure to meet any particular dimensional requirements occurs in more than two of the measured links, then all the links are to be dimensionally checked.

3.6.17 Should any link be found to be defective or fail to meet the dimensional tolerance requirements or if a five link length of chain exceeds the specified tolerance, the unsatisfactory links are to be removed from the chain, and connecting common links complying with the requirements of 3.7 inserted in their places.

3.6.18 The chain is then to be subjected to a further proof load test and re-examined.

3.6.19 The number of connecting common links which may be used to replace defective links is not to exceed three in any 100 m length of chain. The number and type of joining shackles which may be used are to be subject to the written agreement of the end user.

3.6.20 If a link breaks during proof load testing, a sample consisting of three common links is to be taken from each side of the broken link and subjected to a breaking test as detailed in 3.6.21 and 3.6.22. If either of these samples fails, the proof loaded length of cable is not to be accepted. A thorough examination of all broken links is to be made to determine the cause of failure and, after evaluation, LR will consider the extent of cable which is to be rejected and also the possibility that similar factors to those which caused the failure may also be present in other parts of the cable, or other chain cables. The Surveyor is to be advised in advance of all examinations, with reasonable notice being given.

3.6.21 In addition to the requirements of 3.6.2, three link samples are to be selected by the Surveyors from the completed chain for breaking tests. The number of tests required is to be in accordance with Table 10.3.2. Extra links are to be provided for the mechanical tests detailed in 3.6.25. All test links are to be made as part of the chain cable and are to be heat treated with it. These may be removed from the cable prior to heat treatment provided that each sample is heat treated with, and in the same manner as, the chain it represents and is subjected to the proof load appropriate to the chain grade and diameter prior to selection of the mechanical test specimens. They are to be properly identified with the length of chain they represent.

Table 10.3.2 Frequency of break and mechanical tests

Nominal chain diameter mm	Maximum sampling interval m (*See* Note)
Min. — 48	91
49 — 60	110
61 — 73	131
74 — 85	152
86 — 98	175
99 — 111	198
112 — 124	222
125 — 137	250
138 — 149	274
150 — 162	297
163 — 175	322
176 — 186	346
187 — 199	370
199 — 210	395

NOTE
If the sampling interval contains links made from more than one cast, extra break and mechanical tests are required so that tests are made on every cast.

3.6.22 Breaking test specimens are to withstand the load given in Table 10.3.1 for the appropriate grade and size of cable for a period of 30 seconds. The specimen is considered to have passed this test if it has shown no sign of fracture after application of the required load.

3.6.23 If a breaking test specimen fails, two further specimens are to be cut from the same sampling length and both are to be subjected to the breaking test load. If one of the re-test specimens fails the length is to be rejected. All the broken links are to be subjected to an investigation into the cause of failure. LR will then decide which lengths of chain can be accepted and on further action.

3.6.24 For large diameter cables where the required breaking load is greater than the capacity of the testing machines, special consideration will be given to acceptance of an alternative testing procedure.

3.6.25 One tensile and three sets of Charpy V-notch impact test specimens are to be taken from links cut from the heat treated and proof loaded chain at intervals no greater than those indicated in Table 10.3.2 provided that every cast is sampled. The tensile specimen and one set of impact specimens are to be taken from the side of the link opposite the weld. One set of impact test specimens is to have the notches positioned at the centre of the flash butt weld and the third set is to be taken from the bend. All the specimens are to be taken from positions in accordance with Fig. 10.3.4.

3.6.26 The frequency of testing at the link bends may be reduced at the discretion of LR provided it can be verified that the required toughness is achieved consistently.

3.6.27 The results of the mechanical tests are to comply with the requirements of Table 10.3.3.

Table 10.3.3 Mechanical properties of chain cable materials

Grade	Yield stress N/mm^2 minimum	Tensile strength N/mm^2	Elongation % minimum	Reduction of area % minimum (*See* Note 3)	Charpy V-notch impact tests		
					Test temperature °C	Average energy J minimum	Average energy flash weld J minimum
R3	410 (*See* Note 1)	690 minimum (*See* Note 1)	17	50	0 –20 (*See* Note 2)	60 40	50 30
R3S	490 (*See* Note 1)	770 minimum (*See* Note 1)	15	50	0 –20 (*See* Note 2)	65 45	53 33
R4	580 (*See* Note 1)	860 minimum (*See* Note 1)	12	50	–20	50	36
R4S (*See* Note 4)	700 (*See* Note 1)	960 (*See* Note 1)	12	50	–20	56	40
R5 (*See* Note 4)	760 (*See* Note 1)	1000 (*See* Note 1)	12	50	–20	58	42

NOTES
1. The ratio of yield strength to tensile strength should not exceed 0,92.
2. Testing may be carried out at either 0°C or –20°C.
3. For cast fittings, the minimum values for reduction of area are to be 40% for Grades R3 and R3S and 35% for Grades R4, R4S and R5.
4. The maximum hardness for Grade R4S is to be HB330, and for Grade R5 is to be HB340.

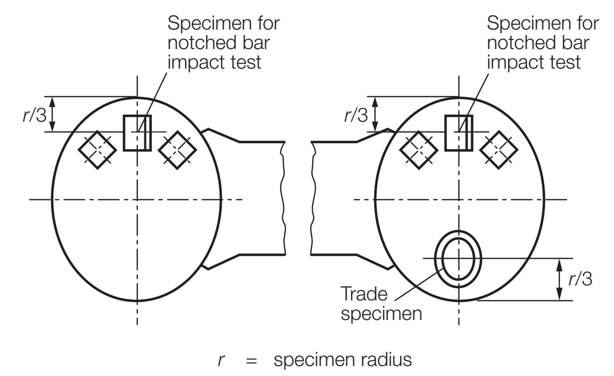


Fig. 10.3.4 Sampling of chain links

3.6.28 If the tensile test requirements are not achieved, two further specimens from the same sample are to be tested. The related length of chain will be considered acceptable if both re-test specimens meet the requirements but failure of either of the re-test specimens will result in rejection of the sampling length of chain represented by the tests.

3.6.29 If the impact test requirements are not achieved, re-tests may be carried out in accordance with Ch 1,2.4. Failure to meet the re-test requirements will result in rejection of the sampling length of chain represented by the tests.

3.6.30 The mass per unit length of stud link mooring cable is to comply with Table 10.3.4.

3.7 Connecting common links or substitute links

3.7.1 Single links to connect lengths of heat treated chain cable or to substitute for test links or defective links without the necessity for re-heat treatment of the whole length of cable are to be made by the chain manufacturer in accordance with an approved procedure. Separate approvals are required for each grade of chain cable and tests are to be made on the maximum size of chain for which approval is sought.

3.7.2 Manufacture and heat treatment of the connecting common link is not to affect the strength of the adjoining links. The temperature reached by these links is nowhere to exceed 250°C.

3.7.3 The steel bar used is to conform with the specification for the chain and approved by LR in accordance with Ch 3,9.

3.7.4 Details of the method of manufacture, including heat treatment, are to be submitted for approval, together with the results of a series of tests laid down by LR.

3.7.5 All links involved in the approval tests are to be destroyed and are not to be used as part of a chain cable.

3.7.6 Every connecting common link included in a chain cable is to be subjected to the proof load appropriate to the grade and size of chain in which it is incorporated as detailed in Table 10.3.1.

Table 10.3.4 Mass per unit length of chain cable

Nominal chain diameter (mm)	Mass per unit length $0{,}0291d^2$ (kg/m)
50	73
55	88
60	105
65	123
70	143
75	164
80	186
85	210
90	236
95	263
100	291
105	321
110	352
115	385
120	419
125	455
130	492
135	530
140	570
145	612
150	655
155	699
160	745
165	792
170	841
175	891
180	943
185	996
190	1051
195	1107
200	1164
205	1223
210	1283

3.7.7 Every connecting common link is to be inspected in accordance with 3.6.5 to 3.6.10.

3.7.8 A second identical link is to be made for mechanical tests which are to be in accordance with 3.6.25. This test link is also to be inspected in accordance with 3.7.7.

3.7.9 Each connecting common link is to be stamped on the stud with the identification marks listed in 3.9.1 plus a unique number for the link. The adjoining links are also to be stamped on the studs.

3.8 Fittings for offshore mooring chain

3.8.1 Cable fittings are to be manufactured at an approved works. Fittings include, but are not limited to, shackles, triplates, end shackles, swivels, and swivel shackles.

3.8.2 The materials from which the fittings are made are to be manufactured at approved works, in accordance with the appropriate requirements of Ch 4,1 or Ch 5,1, and 3.8.3 to 3.8.6. Alternative arrangements may be agreed provided that full details concerning the manufacturer are submitted to LR.

3.8.3 Steel used for fittings must be manufactured by an approved process, and be killed and fine grain treated.

3.8.4 The austenite grain size of steel used for fittings must be 6 or finer as measured in accordance with ASTM E112.

3.8.5 Steel used for forgings or castings for grades R4S and R5 must be vacuum degassed.

3.8.6 For steel used for forgings or castings for grades R4S and R5 the following tests are to be carried out on each heat:

(a) Assessment and quantification of the level of non-metallic micro inclusions. These must be acceptable for the final product.

(b) Macro etching on representative sample, in accordance with ASTM E381 or equivalent, this must be free from any injurious segregation or porosity.

(c) Jominy hardenability tests in accordance with ASTM A255 or equivalent.

The results of these tests are to be supplied by the steel manufacturer, and the results are to be included in the final accessory documentation.

3.8.7 Fittings for chain are to be heat treated in accordance with procedures that have been approved by LR.

3.8.8 All fittings are to be manufactured to a manufacturing specification approved by LR, and provision is to be made for tensile and impact test specimens. The test samples are to be subjected to heat treatment with the fittings they represent. The mechanical test requirements are the same as those for the relevant grade of chain cable, *see* Table 10.3.3.

3.8.9 A batch is defined as fittings from the same heat of steel that have been part of the same heat treatment charge.

3.8.10 Mechanical tests for fittings are to be taken from full size fittings that have been heat treated with the production batch they represent, and the tests are to be taken after the fitting has been proof load tested. It is not permitted to use separate representative coupons unless approved by LR in accordance with 3.8.14.

3.8.11 Forged shackle bodies and forged Kenter shackles are to have a set of three Charpy impact tests and a tensile test taken from the crown of the shackle. For smaller diameter shackles, where the geometry does not allow for the tensile test to be taken from the crown, this may be taken from the straight portion from the locations specified in Fig. 10.3.5, with the Charpy impact test specimens on the outside radius.

3.8.12 The test pieces for cast shackle bodies and cast Kenter shackles can be taken from the straight portion of the fitting from the locations shown in Fig. 10.3.5.

3.8.13 For fittings with complex geometries the locations of test pieces taken are to be approved by LR.

3.8.14 Where fittings are produced in small batches (less than 5) alternative testing may be approved; a proposal must be submitted in a written procedure for consideration.

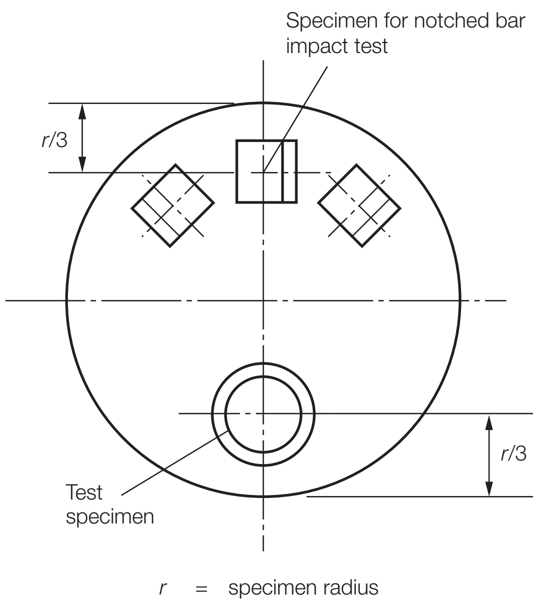


Fig. 10.3.5
Sampling of steel bars, forgings and castings

3.8.15 Mechanical tests of pins are to be taken as shown in Fig. 10.3.6 from the mid length of a sacrificial pin of the same diameter as the final pin. For oval pins, the diameter taken is to represent the smaller dimension. Mechanical tests may be taken from an extended pin of the same diameter as the final pin that incorporates a test prolongation and a heat treatment buffer prolongation, where equivalence with mid length test values have been established. The length of the buffer is to be at least equal to 1 pin diameter which is removed after the heat treatment cycle is finished. The test coupon can then be removed from the pin. The buffer and test are to come from the same end of the pin, as shown in Fig. 10.3.6.

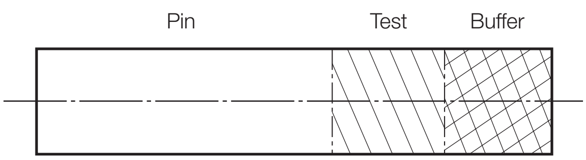


Fig. 10.3.6
Buffer and test piece location for pins

3.8.16 Manufacturers intending to supply accessories in the machined condition (e.g. Kenter type shackles) are to submit detailed drawings for approval by LR.

3.8.17 All chain cable accessories, including spares, are to be subjected to the proof loads appropriate to the grade and size of cable for which they are intended, *see* Table 10.3.1. Prior to this test, the accessories are to be shot or sand blasted to ensure that their surfaces are free from scale, paint or any other coating which could interfere with any subsequent inspection.

3.8.18 The appropriate breaking load as required by Table 10.3.1 is to be applied to at least one item out of every batch of up to 25, and this item is to be destroyed and not used as part of an outfit.

3.8.19 If the sample fails to withstand the breaking load without fracture, or in the event of failure of any other test, then the entire batch is to be rejected unless the cause of failure has been determined and it can be demonstrated that the condition causing failure is not present in any of the other accessories in the batch. If this can be demonstrated then two more samples from the same batch may be tested. If either of these samples fails, the batch is to be rejected.

3.8.20 For very large fittings where the required breaking load is greater than the capacity of the testing machine and for individually produced accessories or accessories produced in small batches, proposals for an alternative method of testing will be given special consideration. All proposals for alternative testing methods are to be detailed in writing and submitted.

3.8.21 At least one accessory from each batch is to be checked dimensionally after proof load testing. The manufacturer is to provide a statement that the dimensions comply with the specified requirements.

3.8.22 The following tolerances apply of the unmachined dimensions of all fittings;
(a) nominal diameter plus 5 per cent, minus 0 per cent; and
(b) other dimensions plus or minus 2,5 per cent.

3.8.23 All accessories are to be subjected to close visual examination after proof load testing, particular attention being paid to machined surfaces and highly stressed regions. All accessories are also to be examined by magnetic particle or dye penetrant inspection and ultrasonic testing. All NDE is to be carried out in accordance with 3.6.9 and 3.6.10. The manufacturer is to provide a statement that the non-destructive examination has been carried out with satisfactory results; this statement is to include reference to the techniques used and the operator's qualifications.

3.8.24 All testing is to be carried out to the satisfaction and in the presence of the Surveyor.

3.8.25 Fittings with increased dimensions, or fittings of a higher material grade, may be specially approved and included in an outfit, provided that;
(a) each item is successfully tested at the required breaking load for the chain cable for which they are intended; and
(b) items of increased dimensions are so designed that their breaking strength is not less than 1,4 times the Rule minimum breaking load for the chain cable for which they are intended, and this has been verified by procedure tests.

3.9 Identification

3.9.1 Each length of chain is to be permanently marked with the following:

(a) LR and abbreviated name of LR's local office issuing the certificate.
(b) Certificate number (this may be abbreviated provided it is stated in the certificate).
(c) Grade and proof load of chain.

3.9.2 The chain is to be marked as follows:

(a) at each end (the marking should identify the leading and tail end of each chain),
(b) at intervals not exceeding 100m,
(c) on all connecting common links or shackles and the immediately adjacent links,
(d) on the first and last common link of each individual charge used in the continuous length.

3.9.3 All identification marks are to be made on the studs and are to be permanent and legible throughout the expected service life of the chain.

3.10 Documentation

3.10.1 A complete Chain Inspection and Testing Report, in booklet form, is to be provided by the chain manufacturer for each continuous chain length, and for each order for chain and fittings. It is to include all dimensional checks, test and inspection reports, non-destructive test reports, process records, as well as any non-conformity, together with corrective action and repair work.

3.10.2 All documents, including reports and appendices, are to contain a reference to the relevant certificate number.

3.10.3 The chain manufacturer is responsible for storing all the documentation in a safe and retrievable manner for a period of at least 10 years.

3.11 Certification

3.11.1 An LR certificate is to be issued for each continuous single length of chain, and each type of fitting, *see* Ch 1,3.1.

3.11.2 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Description and dimensions.
(c) Grade of chain cable.
(d) Identification mark which will enable the full history of the chain to be traced.
(e) Chemical composition.
(f) Details of heat treatment.
(g) Mechanical test results.
(h) Breaking test load.
(j) Proof load.
(k) The number and locations of all connecting common links and all marked links.

■ *Section 4*
Studless mooring chain cables

4.1 Scope

4.1.1 Provision is made in this Section for five grades, R3, R3S, R4, R4S and R5 of studless flash butt welded chain cable intended for long term mooring applications.

4.1.2 The chain is generally expected to be deployed only once for a pre-determined service life.

4.1.3 Each studless chain link design will require to be approved by LR. The plan submitted for this approval is to include the minimum proof and breaking test loads, and the chain mass calculations.

4.2 Manufacture

4.2.1 All the requirements of 3.2, with the exception of that relating to studs, apply to the manufacture of studless mooring chain cables.

4.3 Shape and dimensions of links

4.3.1 The shape and dimensions of the links are to be in accordance with the approved design.

4.4 Dimensional tolerances

4.4.1 The dimensional tolerances of studless links are to be in accordance with the requirements of 3.3.1 to 3.3.7.

4.5 Heat treatment

4.5.1 Heat treatment of the chain is to be in accordance with the requirements of 3.5.

4.6 Testing of completed chain

4.6.1 All chain cables are to be tested in the presence of a Surveyor, at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention must be given to any relevant statutory requirements of the National Authority of the country in which the ship is to be registered.

4.6.2 The entire length of chain cable is to be subjected to a proof load test in an approved testing machine and is to withstand the load given in Table 10.3.1 for the appropriate grade and diameter of the chain, *see also* 4.1.3.

4.6.3 Inspection after proof load testing is to be in accordance with the requirements given in 3.6.3 to 3.6.20, excluding that related to checking of studs in 3.6.5.

4.6.4 In addition to the inspection of the flash butt welded areas as required in 3.6.6, the surfaces of the bends of at least 10 per cent of the links are to be examined by magnetic particle inspection and are to be free from cracks or other defects.

4.6.5 If stretching of links is required in order to maintain dimensional tolerances, the load applied is not to exceed the proof load by more than 10 per cent, and only random lengths of the chain need to be stretched.

4.6.6 Breaking load tests are to be carried out in accordance with 3.6.21 to 3.6.23 and Tables 10.3.1 and 10.3.2.

4.6.7 Alternative procedures to breaking load testing (*see* 3.6.24) are not permissible unless prior agreement is given by LR after special consideration.

4.6.8 Mechanical testing is to be carried out in accordance with 3.6.25 to 3.6.30 and Table 3.3.4.

4.6.9 The weight of the chain cable is to be in accordance with the approved plan.

4.7 Connecting or substitute links

4.7.1 Connecting links and substitute links are to be in accordance with the requirements of 3.7.

4.8 Fittings

4.8.1 Fittings for studless chain are to comply with the requirements of 3.8.

4.9 Identification

4.9.1 All chain and each fitting is to be identified in accordance with 3.9.1 and 3.9.2.

4.9.2 Identification marks are to be made on the outside of the straight part of the link, opposite the flash butt weld.

4.10 Certification

4.10.1 Certificates are to be issued in accordance with 3.11.

4.11 Documentation

4.11.1 Documentation in accordance with 3.11 is to be provided by the manufacturer.

■ *Section 5* Short link chain cables

5.1 Scope

5.1.1 This Section gives the requirements for electrically welded steel short link chain cable for marine use but excluding those applications covered by the *Code for Lifting Appliances in a Marine Environment*.

5.1.2 Provision is made for grade M(4), as defined in ISO 1834:1999. Allowance is also made for the requirements of ISO 4565.

5.2 Manufacture

5.2.1 Short link chain cables are to be manufactured at works approved by LR. A list of approved manufacturers for short link chain cable is published separately by LR.

5.2.2 The chain is to be supplied in either the normalised or quenched and tempered condition. Heat treatment is to be carried out prior to proof and breaking load testing.

5.2.3 The chain may be galvanised using a hot dipping process provided that this is carried out prior to proof and breaking load testing. If galvanised, it is recommended that the thickness of the zinc coating be not less than 70 microns.

5.2.4 Unless otherwise agreed, the finished chain is to be free from coatings other than zinc.

5.3 Bar material

5.3.1 Bars for the manufacture of short link chain cable are to be made and tested in accordance with the appropriate requirements of Ch 3,1 and to the requirements of an International or acceptable National Standard.

5.3.2 The bars are to be made at a works approved by LR.

5.3.3 The steel is to be fully killed and fine grain treated.

5.3.4 The steel is to have mechanical properties which will allow the chain to meet the mechanical test requirements of 5.4.7 and Table 10.5.1.

5.4 Testing and inspection of chain cables

5.4.1 All chain cable of 12,5 mm diameter and above, and all steering chains irrespective of diameter, are to be tested in the presence of a Surveyor at a proving establishment recognised by LR. A list of recognised proving establishments is published by LR. In addition to the requirements stated in this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the ship or other marine structure is to be registered.

Table 10.5.1 Mechanical test requirements for short link chain cables

Chain diameter mm	Grade M(4) Proof load kN	Grade M(4) Breaking load minimum kN
5	7,9	15,8
6,3	12,5	25
7,1	15,9	31,8
8	20,2	40,4
9	25,5	51
10	29,5	63
11,2	31,5	79
12,5	49,1	98,2
14	63	126
16	81	162
18	102	204
20	126	252
22,4	158	316
25	197	394
28	247	494
32	322	644
36	408	816
40	503	1006
45	637	1274

5.4.2 For chain of diameter less than 12,5 mm, other than steering chains, the manufacturer's tests will be acceptable.

5.4.3 After completion of all manufacturing processes, including heat treatment and galvanising, the whole of the chain is to be subjected to the appropriate proof load specified in Table 10.5.1.

5.4.4 The whole of the chain is to be inspected after the proof load test and is to be free from significant defects.

5.4.5 At least one sample, consisting of seven or more links, is to be selected by the Surveyor from each 200 m or less of chain for breaking load tests. Two additional links may be required for engagement in the jaws of the testing machine. These extra links are not to be taken into account in determining the total elongation, *see* 5.4.7.

5.4.6 The breaking load is to comply with the appropriate requirements of Table 10.5.1.

5.4.7 The total elongation of the breaking load sample at fracture, expressed as a percentage of the original inside length of the sample after proof loading, is to be not less than 20 per cent.

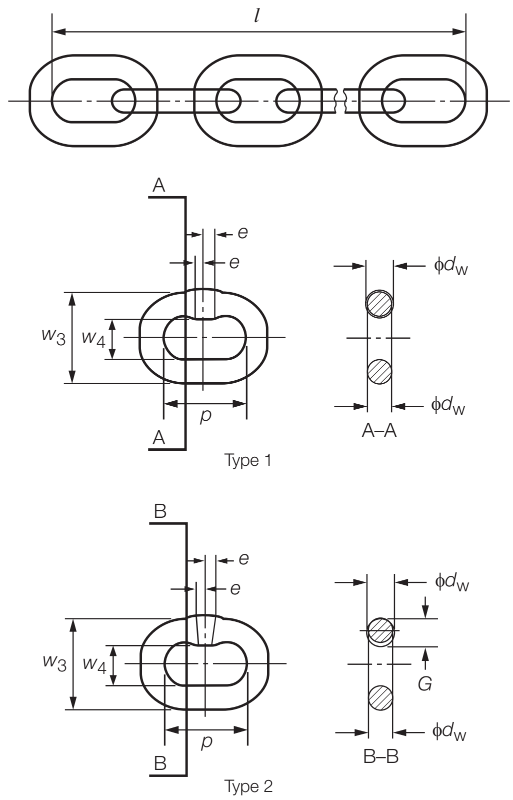
5.5 Dimensions and tolerances

5.5.1 The form and proportions of links are to be in accordance with Fig. 10.5.1.

5.5.2 Manufacturing tolerances are to be within the following limits:

Nominal diameter, d_n	± 5%
Pitch of chain, p_1	± 3%
Length measured over 11 links, l	± 2%
Inside width, w_1	1,35d_n minimum
Outside width, w	3,6d_n maximum

The tolerances are to apply after galvanising. All measurements are to be taken after proof testing.



l = multiple pitch length
p = pitch (internal link length)
d_n = measured diameter of the material, except at the weld
d_w = measured diameter of the material at the weld (Type 1) or weld dimension perpendicular to the plane of the link (Type 2)
G = dimension in other planes as per individual chain specification (Type 2)
e = length affected by welding, on either side of the centre link
w_1 = internal link width away from the weld
w_2 = external link width away from the weld
w_3 = external link width over the weld
w_4 = internal link width at the weld

Fig. 10.5.1 Form and proportions of links

5.6 Identification

5.6.1 All lengths of cable are to be stamped with the following identification marks:
(a) Inspector's mark and date.
(b) Reference mark or number of certificate.
(c) Manufacturer's mark or name.
(d) Chain cable quality mark, M, is to be stamped on at least each twentieth link or at intervals of one metre, whichever is the lesser distance.

5.6.2 Where the inspection is performed under LR's supervision, the inspector's mark and date are to be replaced by LR and the abbreviated name of LR's local office issuing the certificate.

5.7 Certification

5.7.1 The manufacturer is to supply the Surveyor with a certificate stating compliance with an appropriate ISO standard, and also, in the event of the requirements of 5.4 being undertaken other than in the presence of the Surveyor, stating that the test and inspection requirements have been complied with at a recognised proving establishment.

5.7.2 Each test certificate is to include the following particulars:
(a) the quality and description of chain,
(b) identification mark,
(c) nominal size of chain,
(d) proof load,
(e) breaking load,
(f) total elongation at fracture,
(g) where appropriate, the name of the proving establishment.

■ *Section 6* Steel wire ropes

6.1 Scope

6.1.1 Provision is made in this Section for the requirements for the manufacture, testing and certification of steel wire ropes intended to be used for general marine purposes, as well as permanent anchoring, mooring and marine lifting applications.

6.2 General requirements

6.2.1 For general marine purposes, such as stream wires, towlines and ship mooring lines, the construction is to be in accordance with Table 10.6.1. The construction, diameter and strength of steel wire ropes for permanent offshore applications, such as mooring, anchoring and lifting, are covered by other LR Rules. Alternative applications of wire ropes may be accepted, subject to special consideration.

6.2.2 The manufacturer's plant and method of production are to be approved by LR. A list of approved manufacturers of steel wire ropes is published annually in the *List of Approved Manufacturers of Materials*.

6.2.3 For shaped wire, for example, for large diameter ropes for permanent mooring, where there are no established Standards, the manufacturer is to provide evidence by way of test reports that specifications have been developed and agreed with the purchaser and LR for the purposes intended.

6.3 Steel wire for ropes

6.3.1 Steel wire is to be of homogeneous quality, uniform strength and free of defects likely to impair the manufacture and performance of the rope.

6.3.2 For all ropes, the specified minimum tensile strength of the wire is to be 1420, 1570, 1770 or 1960 N/mm^2. The specified minimum tensile strength of the wire is the designated grade for the rope, unless otherwise defined by the purchaser's specification. The actual tensile strength of the wire is not to exceed 120 per cent of the specified minimum tensile strength.

Table 10.6.1 Recommended rope construction

Purpose	Construction of rope			Construction of strands
	Strands	Wires	Core	
Stream wires, towlines and mooring lines	6	24	Fibre	15 over 9 over fibre core
	6	37	Fibre	18 over 12 over 6 over 1
	6	26	Fibre	10 over (5 + 5) over 5 over 1
	6	31	Fibre	12 over (6 + 6) over 6 over 1
	6	36	Fibre	14 over (7 + 7) over 7 over 1
	6	41	Fibre	16 over (8 + 8) over 8 over 1
	6	30	Fibre	18 over 12 over fibre core
Towlines and mooring lines used in association with mooring winches	6	31	7 x 7 wire rope	12 over (6 + 6) over 6 over 1
	6	36	7 x 7 wire rope	14 over (7 + 7) over 7 over 1
	6	41	7 x 7 wire rope	16 over (8 + 8) over 8 over 1

6.3.3 For new rope construction, the manufacturer is to carry out prototype testing suitable for the application of the rope and this is to include tests on wire used for the construction.

6.3.4 Tensile and torsion tests, coating, and adhesion (wrap) tests are to be carried out on wire used for the manufacture of rope.

6.3.5 At least 10 per cent of the spools used for the manufacture of the strand are to be tested. The manufacturer is to demonstrate that tests have been carried out on at least one wire intended for each of the outer and inner strands, and for each diameter and grade used.

6.3.6 The heat number, wire diameter and strength of wire used for a particular construction are to be recorded by the manufacturer.

6.3.7 Torsion tests are to be carried out on the wire by causing one or both of the securing vices to be revolved until fracture occurs (a tensile load not exceeding two per cent of the breaking load of the wire may be applied to keep the wire stretched).

6.3.8 The uncoated wire is to withstand, without fracture, the number of complete twists given for Grades 1 or 3 in Table 10.6.2.

6.3.9 The galvanised wire is to withstand, without fracture, the number of complete twists given in the specification, as agreed with the purchaser and LR. In the absence of a suitable specification, the results are to comply with Table 10.6.2.

6.3.10 Hot dipped galvanised steel wire is to be used for the manufacture of ropes for marine applications. Depending upon the application, the coating may comply with any of the grades in Table 10.6.3. Grades 1 and 2 are heavy coatings. Grade 3 is the minimum coating weight where the galvanising is carried out prior to final wire drawing. Uncoated wire may be considered for approved applications.

6.3.11 The mass per unit area of the zinc coating is to be determined in accordance with a recognised National or International Standard.

6.3.12 Zinc coating tests are to be carried out for each designated grade of wire. The manufacturer is to demonstrate that the coatings are continuous and uniform and suitable for the intended purpose.

6.3.13 Unless otherwise specified by the purchaser, zinc coating tests are to be carried out on the wire prior to stranding.

6.3.14 The adhesion of the coating is to be tested by wrapping the wire round a cylindrical mandrel for 10 complete turns. The ratio between the diameter of the mandrel and that of the wire is to be as in Table 10.6.4. After wrapping on the appropriate mandrel, the zinc coating is to have neither flaked nor cracked to such an extent that any zinc can be removed by rubbing with a cloth.

Table 10.6.2 Torsion test

Diameter coated wire mm	Minimum number of twists					
	Grade 2		Grade 1 or 3			
	Minimum strength N/mm^2		Minimum strength N/mm^2			
	1570	1770	1420	1570	1770	1960
<1,3	19	18	29	26	23	23
≥1,3 <2,3	18	17	26	24	21	21
≥2,3 <3,0	16	14	24	22	—	19
≥3,0 <4,0	12	10	20	18	—	17
≥4,0 <4,6	—	—	18	16	—	—
≥4,6 <5,0	—	—	16	14	—	—
≥5,0 <6,0	—	—	14	11	—	—

NOTE
The minimum test length is 100*d* or 300 mm, where *d* is the wire diameter.

Table 10.6.3 Zinc coating

Diameter of coated wire mm	Zinc coating, minimum g/m^2 Grade1	Grade 2	Grade 3
≥0,20 <0,25	—	30	20
≥0,25 <0,33	—	45	30
≥0,33 <0,40	—	60	30
≥0,40 <0,50	60	75	40
≥0,50 <0,60	70	90	50
≥0,60 <0,80	85	110	60
≥0,80 <1,00	95	130	70
≥1,00 <1,20	110	150	80
≥1,20 <1,50	120	165	90
≥1,50 <1,90	130	180	100
≥1,90 <2,50	—	205	110
≥2,50 <3,20	—	230	125
≥3,20 <4,00	—	250	135

Table 10.6.4 Wrap test for adhesion of coating

Coating	Diameter of coated wire mm	Maximum ratio of mandrel to wire diameter
Grade 1 and 2	<1,5	4
	≥1,5	6
Grade 3	<1,5	2
	≥1,5	3

6.4 Tests on completed ropes

6.4.1 Every length of wire rope is to be subjected to a breaking strength test.

6.4.2 A sample of sufficient length is to be provided for the breaking load test. The rope ends are to be enclosed in a suitable socket. Testing is to be carried out in accordance with a recognised National or International Standard.

6.4.3 The rope may be subject to cyclic loading for bedding purposes prior to testing. The rope is to be tested at a suitable strain rate in accordance with a recognised National or International Standard.

6.4.4 The load is to be applied until one wire break is witnessed or 130 per cent of the minimum breaking load is recorded. The maximum recorded load is to be reported by the manufacturer.

6.4.5 Tests in which a breakage occurs adjacent to and as a result of damage from the grips are to be rejected, if the applied load is less than the specified minimum requirement. The rope is to be retested to withstand the agreed minimum breaking load.

6.4.6 With the exception of offshore mooring ropes, consideration may be given to determining the breaking load by summation or aggregating actual test results on individual wires, if facilities are not available for undertaking a breaking test on a production basis. A suitable spin factor or lay-up deduction allowance in accordance with a recognised National or International Standard for the applicable rope diameter, designated grade and construction is to be applied.

6.4.7 Where spin factors or lay-up deduction allowances are proposed by the manufacturer, a report on suitable cyclic load testing of prototype ropes of the same construction, strength and diameter is to be approved by LR. In addition, the manufacturer is to show that a satisfactory breaking load test has been carried out in the previous two years, and witnessed by LR for the same rope construction, diameter and designated grade.

6.4.8 LR may give special consideration to spin factors or lay deductions based on data extrapolated from smaller diameter ropes of the same construction, provided that these ropes have been tested in accordance with 6.4.7.

6.4.9 All data arising from smaller diameter ropes for the extrapolation in 6.4.8 are to have been derived from tests carried out within two years of the manufacture of the larger diameter rope.

6.4.10 The finished rope is to have no more than one wire connecting weld in any length of 18d, where d is the diameter of the rope.

6.5 Inspection

6.5.1 A report on dimensional and visual examination is to be presented to the Surveyor by the manufacturer. The dimensions and discard criteria are to comply with an agreed National or International Standard.

6.5.2 Visual and dimensional checks are to be carried out in the presence of the Surveyor.

6.6 Identification

6.6.1 All completed ropes are to be identified with attached labels detailing the rope type, diameter and length.

6.7 Certification

6.7.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

6.7.2 Each test certificate is to contain the following particulars:

- Purchaser's name and order number.
- Details of the rope construction.
- Core material.
- Grade of zinc coating.
- Mechanical test results.
- Adhesion test results.
- Dimensions.
- Method of breaking load testing.
- Breaking load.

■ *Section 7* Fibre ropes

7.1 Manufacture

7.1.1 Fibre ropes intended as mooring lines may be made of coir, hemp, manila or sisal, or may be composed of synthetic (man-made) fibres. They may be three-strand (hawser laid), four-strand (shroud laid) or nine-strand (cable laid), but other constructions will be specially considered.

7.1.2 Each length of rope is to be manufactured from suitable material of good and consistent quality. Rope materials should, in general, comply with a recognised National Standard.

7.1.3 Synthetic fibre ropes are to be suitable for the purpose intended and should comply with a recognised standard.

7.1.4 Weighting and loading matter is not to be added, and any lubricant is to be kept to a minimum. Any rot-proofing or water repellancy treatment is not to be deleterious to the fibre nor is it to add to the weight or reduce the strength of the rope.

7.2 Tests of completed ropes

7.2.1 The breaking load is to be determined by testing to destruction a sample cut from the completed rope.

7.2.2 The minimum test length and the initial test load are to be as given in Table 10.7.1. After application of the initial load, the diameter and evenness of lay up of the sample are to be checked. The sample is then to be uniformly strained at the rate given in Table 10.7.1 until it breaks.

7.2.3 The actual breaking load is to be not less than that given in an appropriate National Standard.

Table 10.7.1 Breaking load test

Material	Test length mm minimum	Initial load % (*see* Note)	Rate of straining mm/min
Natural fibre	1800	2	150 ± 50
Synthetic fibre	900	1	100 max.
NOTE Percentage of specified minimum breaking load.			

7.2.4 If the sample is held by grips and the break occurs within 150 mm of the grips, the test may be repeated, but not more than two tests may be made on any one coil.

7.2.5 Where difficulty is experienced in testing a sample of a completed synthetic fibre rope, LR will consider alternative methods of testing.

7.3 Identification

7.3.1 Each coil of rope is to be identified with an attached label detailing the material, construction, diameter and length.

7.4 Certification

7.4.1 A manufacturer's certificate, in accordance with Ch1,3.1.3(c), is to be issued. The certificate is to be validated by the manufacturer's representative, who is to be independent of the production process and LR.

7.4.2 Each test certificate is to include the following particulars:
- Manufacturer's name.
- Purchaser's name and order number.
- Rope type.
- Dimensions.
- Test length.
- Rate of straining.
- Breaking load.

■ *Section 1* General

1.1 Scope

1.1.1 Provision is made in this Chapter for the approval by Lloyd's Register (hereinafter referred to as 'LR') of electrodes, wires, fluxes and other consumables intended for use in the welding of the following types of materials:

(a) Steel of various grades as represented by Grade A through to Grade FH69, *see* Sections 3 to 7.
(b) A wide range of low-temperature service steels, *see* Sections 3 to 7.
(c) Stainless steels including nitrogen strengthened grades and some of the duplex varieties, *see* Section 8.
(d) Aluminium alloys, *see* Section 9.

1.1.2 For this purpose, welding, consumables are categorised and subject to the special requirements of different Sections of this Chapter.

(a) Covered electrodes for manual welding and gravity welding.
(b) Combinations of wire and flux for automatic submerged-arc welding.
(c) Combinations of wire and gas for gas metal-arc welding and wires for self-shielding welding.
(d) Combinations for electro-slag and electro-gas welding.
(e) Combinations with temporary backing materials for one-side welding.
(f) Consumables for welding austenitic and duplex stainless steels.
(g) Combinations for welding aluminium.

1.2 Grading

1.2.1 Consumables for welding structural steels are graded into ten strength levels, and each of these is further subdivided into several levels in respect of notch toughness. The five basic levels of toughness are indicated by a number (1 to 5). Normal tensile strength is indicated by 'N'. Higher tensile strength is indicated by 'Y', and if the yield strength is higher than 375 N/mm^2 the Y is followed by a number (40 to 69), as shown in Table 11.1.1.

1.2.2 In addition to the grade, consumables are also allocated a suffix indicating the welding technique used. These are defined in the context of the following Sections of this Chapter.

1.2.3 Consumables for structural and low temperature service steels may be controlled low hydrogen and approved as such. Grade marking H15, H10 or H5 will be applied, as appropriate.

1.2.4 For joining higher strength steels, approval granted for 1Y consumables will be limited to maximum material thickness of 25 mm.

1.2.5 Test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grade.

1.2.6 Further details of grading are given in subsequent Sections of this Chapter.

1.3 Manufacture

1.3.1 The manufacturer's plant and method of production of welding consumables are to be such as to ensure reasonable uniformity in manufacture.

1.4 Approval procedures

1.4.1 Welding consumables will be approved subject to a satisfactory inspection of the works by the Surveyor for compliance with the test requirements detailed in subsequent Sections in this Chapter.

1.4.2 The test assemblies are to be prepared under the supervision of the Surveyor, and using samples selected by him. All tests are to be carried out in his presence.

1.4.3 For Charpy V-notch tests, a set of three test specimens is to be prepared and the average energy value is to comply with the requirements of subsequent Sections in this Chapter. One individual value may be less than the required average value provided that it is not less than 70 per cent of this value.

1.4.4 Where chemical analysis is required for approval, the results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

Table 11.1.1 Welding consumable grades appropriate to structural and low temperature service steel grades

Consumable grade	Suitable for steel grades (*see* Notes)			
1. Ship Grade Steels (Ch 3,2 and Ch 3,3)				
1N	A	***AH27S***	—	—
2N	B, D	***DH27S***	—	—
3N	E	***EH27S***	—	—
1Y	A	***AH27S***	***AH32***	***AH36***
2Y	B, D	***DH27S***	***DH32***	***DH36***
3Y	E	***EH27S***	***EH32***	***EH36***
4Y	—	***FH27S***	***FH32***	***FH36***
2Y40	***AH32***	***AH36***	***AH40***	—
2Y40	***DH32***	***DH36***	***DH40***	—
3Y40	***EH32***	***EH36***	***EH40***	—
4Y40	***FH32***	***FH36***	***FH40***	—
5Y40	***FH32***	***FH36***	***FH40***	—
2Y47	—	—	***AH40***	***AH47***
2Y47	—	—	***DH40***	***DH47***
3Y47	—	—	***EH40***	***EH47***
4Y47	—	—	***FH40***	***FH47***
2. High Strength Steels (Ch 3,10) *see* Note 3				
3Y42	***AH36***	***AH40***	AH42	—
3Y42	***DH36***	***DH40***	DH42	—
4Y42	***EH36***	***EH40***	EH42	—
5Y42	***FH36***	***FH40***	FH42	—
3Y46	***AH40***	AH42	AH46	—
3Y46	***DH40***	DH42	DH46	—
4Y46	***EH40***	EH42	EH46	—
5Y46	***FH40***	FH42	FH46	—
3Y50	AH42	AH46	AH50	—
3Y50	DH42	DH46	DH50	—
4Y50	EH42	EH46	EH50	—
5Y50	FH42	FH46	FH50	—
3Y55	AH50	AH55	—	—
3Y55	DH50	DH55	—	—
4Y55	EH50	EH55	—	—
5Y55	FH50	FH55	—	—
3Y62	AH55	AH62	—	—
3Y62	DH55	DH62	—	—
4Y62	EH55	EH62	—	—
5Y62	FH55	FH62	—	—
3Y69	AH62	AH69	—	—
3Y69	DH62	DH69	—	—
4Y69	EH62	EH69	—	—
5Y69	FH62	FH69	—	—
3. Ferritic Low Temperature Service Steels (Ch 3,6)				
$1\frac{1}{2}$ Ni	$1\frac{1}{2}$ Ni	—	—	—
$3\frac{1}{2}$ Ni	$3\frac{1}{2}$ Ni	—	—	—
5 Ni	5 Ni	—	—	—
9 Ni	9 Ni	—	—	—

NOTES
1. Steel grades shown in bold italic type include the equivalent (LT-xxxx) low temperature service grades referenced in Ch 3,6.
2. The Table applies to the multi-run welding techniques (i.e. m, S, M).
3. Approval of consumables intended for welding high strength steels in Ch 3,10 also includes the standard ship steel grades as shown in bold italic type and equivalent low temperature service steel grades referenced in Ch 3,6.

1.4.5 LR may require, in any particular case, such additional tests or requirements as may be necessary.

1.4.6 A *List of Approved Welding Consumables* is published by LR.

1.4.7 LR is to be notified of any alteration proposed to be made in the process of manufacture subsequent to approval. Sufficient detail is to be provided to determine the need for further testing to maintain the approval.

1.4.8 Consideration will be given to alternative procedures for approval in the case of manufacturers producing consumables under the control of another manufacturer or plant already having approval of one or more products.

1.5 Annual inspection and tests

1.5.1 All establishments where approved welding consumables are manufactured, and the associated quality control procedures, are to be subjected to annual inspection. On these occasions, samples of the approved consumables are to be selected by the Surveyor and subjected to the tests detailed in subsequent Sections in this Chapter. These are to be completed and reported before the end of the one year period beginning at the initial approval date, and repeated annually so as to provide at least an average of one annual test per year.

1.6 Changes in grading

1.6.1 Changes in grading of welding consumables will be considered only at the manufacturer's request, preferably at the time of annual testing. For upgrading in connection with impact properties, and uprating in connection with tensile properties, tests from butt weld assemblies will be required in addition to the normal annual approval tests. For upgrading in connection with hydrogen testing, specific tests will be required in accordance with ISO 3690. Downgrading and downrating may be imposed by LR where tests and re-tests fail to meet the requirements of this Chapter.

1.7 Manufacturers' Quality Assurance Systems

1.7.1 As an alternative to 1.5, manufacturers may seek maintenance of approval based on acceptance by LR of their 'in house' quality assurance system, and by regular audit of that system carried out in accordance with procedures approved by LR.

1.8 Certification

1.8.1 Each carton or package of approved consumables is to contain a certificate from the manufacturer, generally in accordance with the following: 'The <*insert name of manufacturer*> company certifies that the composition and quality of these consumables conform with those of the consumables used in making the test pieces submitted to and approved by the approval bodies nominated on the label of this package.'

Section 2
Mechanical testing procedures

2.1 Dimensions of test specimens

2.1.1 Dimensions of test pieces for deposited metal tensile tests, butt weld tensile tests, bend tests and Charpy V-notch impact test are to machined to the dimensions and tolerances detailed in Chapter 2.

2.2 Testing procedures

2.2.1 The procedures used for all tensile and impact tests are to comply with the requirements of Chapter 2.

2.2.2 Butt weld bend test specimens are to be tested at ambient temperature and are to be bent through an angle of 120° over a former having a diameter which relates to the thickness of the test specimen as detailed in subsequent Sections. For each pair of bend test specimens, one specimen is to be tested with the face of the weld in tension and the other with the root of the weld in tension.

2.2.3 Macro examinations are to be carried out on polished and etched specimens at a maximum magnification not exceeding x10. The examination is to ensure complete fusion, inter-run penetration and freedom of defects.

2.3 Re-testing procedures

2.3.1 Re-testing procedures are to comply with Ch 2,1.4.

Section 3
Electrodes for manual and gravity welding

3.1 General

3.1.1 Dependent on the results of the mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

3.1.2 Approval of an electrode will be given in conjunction with a welding technique indicated by a suffix ‘m’ for manual welding, ‘G’ for gravity or contact electrode and ‘p’ for deep penetration electrode.

3.1.3 If the electrodes are in compliance with the requirements of the hydrogen test given in 3.4, a suffix ‘H15’ or ‘H10’ or ‘H5’ will be added to the grade mark. Table 11.3.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

3.1.4 For each strength level, electrodes which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.3.1 Minimum low hydrogen approval requirements for manual and gravity electrodes

Approval grades	Low hydrogen grade required
1 (1N), 2 (2N), 3 (3N)	NR
2Y, 3Y, 4Y	H15 (*see* Note 2)
2Y40 to 5Y40	H15
2Y47 to 4Y47	H10
3Y42 to 5Y42	H10
3Y46 to 5Y46	H10
3Y50 to 5Y50	H10
3Y55 to 5Y55	H5
3Y62 to 5Y62	H5
3Y69 to 5Y69	H5
1½ Ni	H15
3½ Ni	H15
5 Ni	NR (*see* Note 3)
9 Ni	NR (*see* Note 3)

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

3.1.5 Electrodes approved for normal and higher strength levels up to and including ‘Y’ are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

3.1.6 Electrodes approved for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

3.1.7 Electrodes approved for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

3.1.8 The welding current used is to be within the range recommended by the manufacturer and, where an electrode is stated to be suitable for both a.c. and d.c., a.c. is to be used for the preparation of the test assemblies.

3.1.9 Where an electrode is submitted only for approval for fillet welding and to which the butt weld test provided in 3.3 is not considered applicable, approval tests are to consist of the fillet weld tests as given in 3.5 and deposited metal tests with chemical analyses as given in 3.2.

3.2 Deposited metal test assemblies

3.2.1 The deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one with 4 mm diameter electrodes and the other with 8 mm diameter electrodes, or the largest size manufactured if this is less than 8 mm diameter. If an electrode is available in one diameter only, one test assembly is sufficient. Any of the grades of steel in Table 11.1.1 may be used for the preparation of these assemblies, up to a strength level which is not more than two levels above that for which approval is sought.

3.2.2 For Y47 grades, as an alternative to Fig. 11.3.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

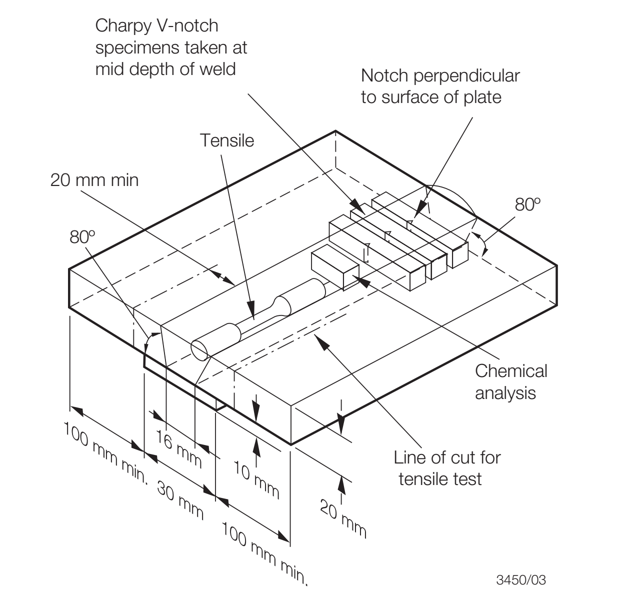


Fig. 11.3.1 Deposited metal test assembly

3.2.3 The weld metal is to be deposited in single- or multi-run layers according to normal practice, and the direction of deposition of each layer is to alternate from each end of the plate, each run of weld metal being not less than 2 mm and not more than 4 mm thick. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.2.4 The chemical analysis of the deposited weld metal in each deposited metal test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

3.2.5 One tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.3.1. Care is to be taken that the axis of the tensile test specimen coincides with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld, with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

3.2.6 The results of all tests are to comply with the requirements of Table 11.3.2 as appropriate.

3.3 Butt weld test assemblies

3.3.1 Butt weld assemblies, as shown in Fig. 11.3.2, are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the electrode is recommended by the manufacturer. In the case of electrodes for normal strength and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), electrodes satisfying the requirements for down-hand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. In all other cases, approval for the horizontal-vertical position will require a butt weld to be made in that position and fully tested.

3.3.2 For Y47 grades, as an alternative to Fig. 11.3.2 the thickness of the plate used for the test assembly may be taken as 50 mm.

3.3.3 Where the electrode is to be approved only in the downhand position, an additional test assembly is to be prepared in that position.

3.3.4 The grades of steel used for the preparation of the test assemblies are to be as follows:

Grade 1 (1N) electrodes	A
Grade 2 (2N) electrodes	A, B or D
Grade 3 (3N) electrodes	A, B, D or E
Grade 2Y electrodes	AH32, AH36, DH32 or DH36
Grade 3Y electrodes	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y electrodes	AH32 AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 electrodes	AH40 or DH40
Grade 3Y40 electrodes	AH40, DH40 or EH40
Grade 4Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 5Y40 electrodes	AH40, DH40, EH40 or FH40
Grade 2Y47 electrodes	AH47, DH47
Grade 3Y47 electrodes	AH47, DH47, EH47
Grade 4Y47 electrodes	AH47, DH47, EH47 or FH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm^2. The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

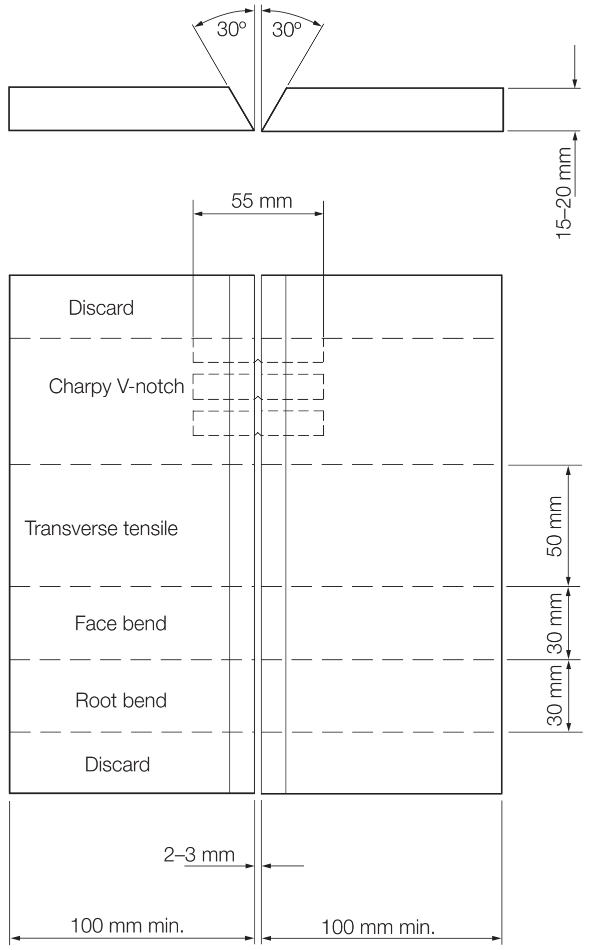


Fig. 11.3.2 Butt weld test assembly

3.3.5 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

3.3.6 The test assemblies are to be made by welding together two plates of equal thickness (15 to 20 mm), not less than 100 mm in width and of sufficient length to allow the cutting out of test specimens of the prescribed number and size. The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root gap 2 to 3 mm. The root face is to be 0 to 2 mm.

3.3.7 The following welding procedure is to be adopted in making the test assemblies:

Downhand (a). The first run with 4 mm diameter electrode. Remaining runs (except the last two layers) with 5 mm diameter electrodes or above according to the normal welding practice with the electrodes. The runs of the last two layers with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Downhand (b) (where a second downhand test is required). First run with 4 mm diameter electrode. Next run with an electrode of intermediate diameter of 5 mm or 6 mm, and the remaining runs with the largest diameter of electrode manufactured or 8 mm whichever is the lesser.

Horizontal-vertical. First run with 4 mm or 5 mm diameter electrode. Subsequent runs with 5 mm diameter electrodes.

Vertical-upward and overhead. First run with 3,25 mm diameter electrode. Remaining runs with 4 mm diameter electrodes or possibly with 5 mm if this is recommended by the manufacturer for the positions concerned.

Vertical-downward. If the electrode being tested is intended for vertical welding in the downward direction, this technique is to be adopted for the preparation of the test assembly using electrode diameters as recommended by the manufacturer.

3.3.8 For all assemblies, the back sealing runs are to be made with 4 mm diameter electrodes in the welding position appropriate to each test sample, after cutting out the root run to clean metal. For electrodes suitable for downhand welding only, the test assemblies may be turned over to carry out the back sealing run.

3.3.9 Normal welding practice is to be used and, between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. After being welded, the test assemblies are not to be subjected to any heat treatment, except in those higher strength grades where it is considered necessary to use the welded joint in the stress-relieved (tempered) condition. In those cases, the code 'sr' will be added to the approval grading.

3.3.10 It is recommended that the welded assemblies be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

3.3.11 The test specimens as shown in Figs. 11.3.2 and 11.3.3 are to be prepared from each test assembly.

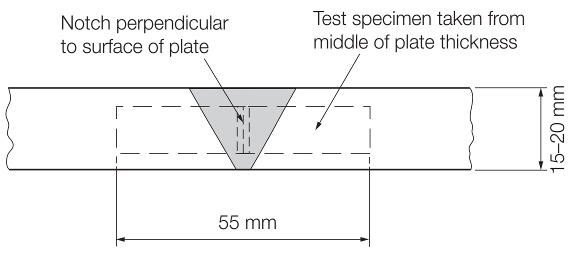


Fig. 11.3.3
Butt weld test assembly position of impact test specimens

Table 11.3.2 Requirements for deposited metal tests (covered electrodes)

Grade (*see* Note 3)	Yield stress N/mm^2 minimum	Tensile strength N/mm^2 (*see* Note 1)	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note 2) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	47
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	47
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	47
2Y47, 3Y47, 4Y47	460	570 – 720	19	0, –20, –40	53
3Y40	400	510 – 690	22	–20	47
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	47
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 – 690	22	–60	47
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
$1^1/_2$ Ni	375	460	22	–80	34
$3^1/_2$ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTES
1. Single values are the minimum requirements.
2. Energy values from individual impact test specimens are to comply with 1.4.3.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

3.3.12 The results of all tensile and impact tests are to comply with the requirements of Table 11.3.3 as appropriate. The position of fracture in the transverse tensile test is to be reported.

3.3.13 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defect exceeding 3 mm in dimensions can be seen on the outer surface.

3.4 Hydrogen test

3.4.1 The hydrogen gradings are specified in 3.1.3. The hydrogen grading required determines the method of testing permitted as shown in Table 11.3.4. Where ISO 3690 is used as the testing method, three test specimens are to be prepared and tested, and all three hydrogen test results must be below the maximum value for the hydrogen mark required.

3.5 Fillet weld test assemblies

3.5.1 Fillet weld assemblies as shown in Fig. 11.3.4 are to be prepared for each welding position (horizontal-vertical, vertical-upward, vertical-downward or overhead) for which the electrode is recommended by the manufacturer. The grade of steel used for the test assemblies is to be as detailed in 3.3.4. The length of the test assembly, *L*, is to be sufficient to allow at least the deposition of the entire length of the largest diameter electrode being tested. Where an electrode is submitted for approval of both butt and fillet welding, approval tests are to include the deposited metal tests as given in 3.2, the butt weld tests as given in 3.3, and only one fillet weld test as given in subsequent paragraphs of this sub-Section welded in the horizontal-vertical position.

Table 11.3.3 Requirements for butt weld tests (covered electrodes)

Grade (*see* Note 3)	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests: Test temperature °C	Charpy V-notch impact tests: Average energy (*see* Note 1) J minimum — All positions (*see* Note 2)
1N, 2N, 3N	400	3	+20, 0, –20	47 (34)
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	47 (34)
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	47 (39)
2Y47, 3Y47, 4Y47	570 – 720	4	0, –20, –40	53
3Y40	510	3	–20	47 (39)
3Y42	530 – 680	4	–20	47
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	47 (39)
4Y42	530 – 680	4	–40	47
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
$1\frac{1}{2}$ Ni	490	3	–80	27
$3\frac{1}{2}$ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to welds made in the vertical position with upward progression.
3. Grade 1Y is not applicable to SMAW consumables referenced in Section 3.

Table 11.3.4 Permitted methods for obtaining low hydrogen grading

Hydrogen Grade	Permitted Method
H15	ISO 3690 (or Glycerine) (*See* Note)
H10	ISO 3690
H5	ISO 3690

NOTE
ISO method preferred.

3.5.2 For Y47 grades, as an alternative to Fig. 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

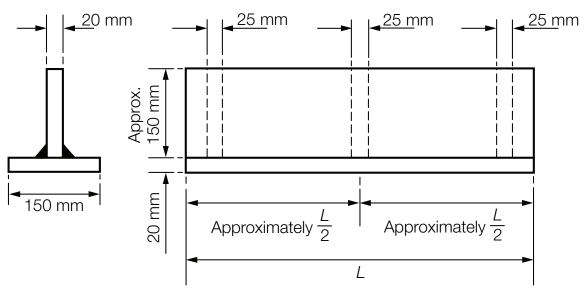


Fig. 11.3.4 Fillet weld test assembly

3.5.3 The electrode sizes to be used are the maximum and minimum diameters recommended by the manufacturer for fillet welding. The first side is to be welded using the maximum diameter. The second side is to be welded only after the assembly has been allowed to cool below 50°C using the minimum diameter. The size of these single run fillet welds will, in general, be determined by the electrode size and the welding current employed during testing and should represent the range of fillet weld bead sizes recommended by the manufacturer.

3.5.4 Each test assembly is to be sectioned to form three macro-sections, each about 25 mm thick. These are to be examined for root penetration, satisfactory profile, freedom from cracking and reasonable freedom from porosity and slag inclusions. Any undercut is not to exceed 0,5 mm in depth. Convexity or concavity of the profile is not to exceed one-tenth of the fillet bead throat dimension. All such observations are to be reported.

3.5.5 Hardness measurements are to be made on the central macro-section only, as shown in Fig. 11.3.5. The results are to be reported.

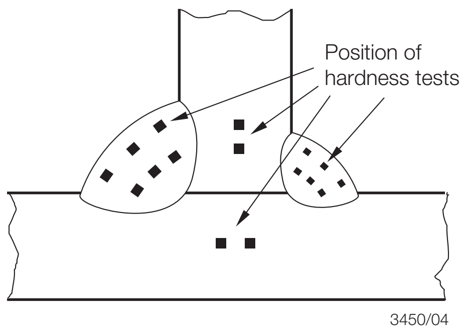


Fig. 11.3.5
Hardness tests for fillet weld test assembly

3.5.6 One of the remaining sections of the assembly is to have the weld on the first side gouged or machined to facilitate breaking the fillet weld on the second side by closing the two plates together, subjecting the root of the weld to tension. On the other remaining section, the weld on the second side is to be gouged or machined and the section fractured using the same procedure. The fractured surfaces are to be examined. They are to show satisfactory penetration, freedom from cracks and reasonable freedom from porosity and this should be reported.

3.6 Electrodes designed for deep penetration welding

3.6.1 Where an electrode is designed solely for the deep penetration welding of downhand butt joints and horizontal-vertical fillets in normal tensile strength steel, only the tests detailed in 3.7 and 3.8 are required for approval purposes.

3.6.2 Electrodes designed solely for the deep penetration welding technique will be approved as complying with Grade 1 requirements only and will be given the suffix ‘p’.

3.6.3 Where a manufacturer recommends that an electrode having deep penetrating properties can also be used for downhand butt welding of thicker plates with prepared edges, the electrode will be treated as a normal penetration electrode, and the full series of tests in the downhand position is to be carried out, together with the deep penetration tests given in 3.7 and 3.8.

3.6.4 Where a manufacturer desires to demonstrate that an electrode, in addition to its use as a normal penetration electrode, also has deep penetrating properties when used for downhand butt welding and horizontal fillet welding, the additional tests given in 3.7 and 3.8 are to be carried out.

3.6.5 Electrodes approved for both normal and deep penetration welding will have the suffix ‘p’ added after the appropriate grade mark for normal penetration welding.

3.6.6 Where the manufacturer prescribes a different welding current and procedure for the electrode when used as a deep penetration electrode and a normal penetration electrode, the recommended current and procedure are to be used when making the test assemblies in each case.

3.7 Deep penetration butt weld test assemblies

3.7.1 Two plates of thickness equal to twice the diameter of the core of the electrode plus 2 mm are to be butt welded together with one downhand run of welding from each side. The plates are to be not less than 100 mm wide and of sufficient length to allow the cutting out of the test specimens of the correct number and size as shown in Fig. 11.3.6. Grade A steel is to be used for these test assemblies. The joint edges are to be prepared square and smooth and, after tacking, the gap is not to exceed 0,25 mm. The test assembly is to be welded using an 8 mm diameter electrode, or the largest diameter manufactured if this is less than 8 mm and the assembly is to be allowed to cool below 50°C between runs.

3.7.2 The test specimens as shown in Figs. 11.3.3 and 11.3.6 are to be prepared from each test assembly.

3.7.3 The results of tensile and impact tests are to comply with the requirements of Table 11.3.3 for Grade 1 electrodes. The position of fracture in the tensile test is to be reported. The bend test specimens are to be in accordance with 3.3.13.

3.7.4 The discards at the end of the welded assemblies are to be not more than 35 mm wide. The joints of these discards are to be polished and etched and must show complete fusion and inter-penetration of the weld beads. At each cut in the test assembly, the joints are also to be examined to ensure that complete fusion has taken place.

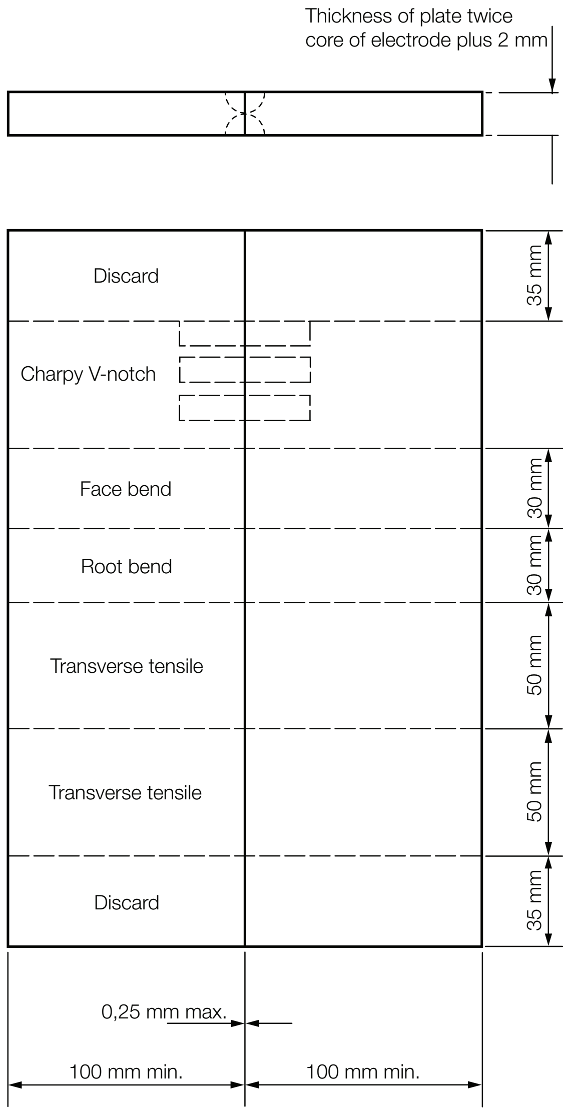


Fig. 11.3.6
Deep penetration butt weld test assembly

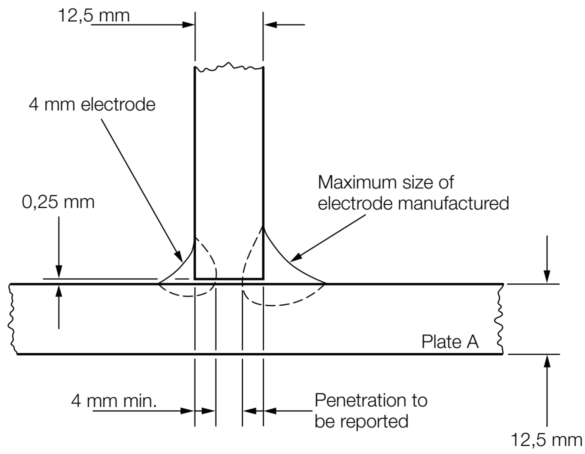


Fig. 11.3.7
Deep penetration fillet weld test assembly

3.8 Deep penetration fillet weld test assemblies

3.8.1 A fillet weld assembly is to be prepared as shown in Fig. 11.3.7 with plates about 12,5 mm in thickness. The welding is to be carried out with one run for each fillet with plate A in the horizontal plane during the welding operations. The length of the fillet is to be 160 mm and the gap between the plates is to be not more than 0,25 mm. Grade A steel is to be used for these test assemblies.

3.8.2 The fillet weld on one side of the assembly is to be carried out with a 4 mm diameter electrode, and that on the other side with the maximum diameter of electrode manufactured. The welding current used is to be within the range recommended by the manufacturer, and the welding is to be carried out using normal welding practice except that the assembly is to be allowed to cool below 50°C between runs.

3.8.3 The welded assembly is to be cut by sawing or machining within 35 mm of the ends of the fillet welds, and the joints are to be polished and etched. The welding of the fillet made with a 4 mm diameter electrode is to show a penetration of 4 mm (*see* Fig. 11.3.7) and the corresponding penetration of the fillet made with the maximum diameter of electrode manufactured is to be reported.

3.9 Electrodes designed for gravity or contact welding

3.9.1 Approval for welding using the gravity, 'G', technique is available for welding only normal strength and higher tensile steels up to and including Grade 36.

3.9.2 Where an electrode is submitted solely for approval for use in contact welding using automatic gravity or similar welding devices, deposited metal tests, butt weld tests and, where appropriate, fillet weld tests similar to those for normal manual electrodes are to be carried out using the process for which the electrode is recommended by the manufacturer.

3.9.3 Where an electrode is submitted for approval for use in contact welding using automatic gravity or similar welding devices in addition to normal manual welding, butt weld and, where appropriate, fillet weld tests, using the gravity or other contact device as recommended by the manufacturer, are to be carried out in addition to the normal approval tests.

3.10 Annual tests

3.10.1 For normal penetration electrodes, the annual tests are to consist of two deposited metal test assemblies. These are to be prepared and tested in accordance with 3.2. If an electrode is available in one diameter only, one test assembly is sufficient.

3.10.2 Where an electrode is approved solely for deep penetration welding, the annual test is to consist of one butt welded test assembly. This is to be prepared and tested in accordance with 3.7.

3.10.3 Where an electrode is approved for both normal and deep penetration welding, annual tests as detailed in 3.10.1 and 3.10.2 are to be carried out.

3.10.4 Where an electrode is approved solely for gravity or contact welding, the annual test is to consist of one deposited metal test assembly using the gravity or other contact device as recommended by the manufacturer.

3.10.5 Where an electrode is approved for both manual and gravity welding, annual tests as detailed in 3.10.1 and 3.10.4 are to be carried out.

■ Section 4
Wire-flux combinations for submerged-arc automatic welding

4.1 General

4.1.1 Wire-flux combinations for single and multiple electrode submerged-arc automatic welding, without the use of temporary backing, are divided into the following two categories:
- For use with the multi-run technique.
- For use with the two-run technique.

Where particular wire-flux combinations are intended for welding with both techniques, tests are to be carried out for each technique.

4.1.2 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

4.1.3 The suffixes T or M will be added after the grade mark to indicate approval for the two-run technique or, multi-run technique respectively.

4.1.4 Wire-flux combinations satisfying the requirements for multi-run or two-run techniques will also be approved for fillet welding in the downhand and horizontal-vertical position, subject to agreement by the manufacturer.

4.1.5 If the consumable combination is in compliance with the requirements of the hydrogen test given in 3.4, a suffix H15, H10 or H5 will be added to the grade. Table 11.4.1 shows the mandatory levels of low hydrogen approval for the various approval grades.

4.1.6 For each strength level, wire-flux combinations which have satisfied the requirements for a higher toughness grade are considered as complying with the requirements for a lower grade.

Table 11.4.1 Minimum low hydrogen approval requirements for wire-flux combinations

Approval grade	'H' grade for Multi-run	'H' grade for Two-run
1 (1N), 2 (2N), 3 (3N)	NR	NR
1Y, 2Y, 3Y, 4Y	NR	NR
2Y40 to 5Y40	H15	NR
2Y47 to 4Y47	H10	H15
3Y42 to 5Y42	H10	H15
3Y46 to 5Y46	H10	H15
3Y50 to 5Y50	H10	H10
3Y55 to 5Y55	H5	H10
3Y62 to 5Y62	H5	H5
3Y69 to 5Y69	H5	H5
$1^1/_2$ Ni	H15	NR
$3^1/_2$ Ni	H15	NR
5 Ni (*see* Note 2)	NR	NR
9 Ni (*see* Note 2)	NR	NR

NOTES
1. NR – Not required. Approval can be obtained when requested.
2. Assumes use of an austenitic, non-transformable, filler material.

4.1.7 Wire-flux combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

4.1.8 Wire-flux combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

4.1.9 Wire-flux combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

4.1.10 Wire-flux combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 4.5.1.

4.1.11 The welding current may be either a.c. or d.c. (electrode positive or negative) according to the recommendation of the manufacturer. If both a.c. and d.c. are recommended, a.c. is to be used for the tests.

4.1.12 Wire-flux combinations for multiple electrode submerged-arc welding will be subject to separate approval tests. These are to be carried out generally in accordance with the requirements of this Section.

4.1.13 Wire-flux combinations are not naturally low hydrogen in character, but for the lower strength grades of steel low hydrogen testing is not normally a requirement for approval. With higher strength steels it is more important and Table 11.4.1 shows the mandatory minimum low hydrogen status required for approval of wire-flux combinations.

4.2 Approval tests for multi-run technique

4.2.1 Where approval for use with the multi-run technique is requested, deposited metal and butt weld tests are to be carried out.

4.3 Deposited metal test assemblies (multi-run technique)

4.3.1 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1, using any of the grades of steel in Table 11.1.1 up to a strength level which is not more than two levels above that for which approval is sought.

4.3.2 For Y47 grades, as an alternative to Fig. 11.4.1, the thickness of the plate used for the test assembly may be taken as 50 mm.

4.3.3 The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case any remaining scale is to be removed from the bevelled edges.

4.3.4 Welding is to be in the downhand position, and the direction of deposition of each run is to alternate from each end of the plate. After completion of each run, the flux and welding slag are to be removed. Between each run, the assembly is to be left in still air until it has cooled to less than 250°C, the temperature being taken in the centre of the weld, on the surface of the seam. The thickness of the layer is to be not less than the diameter of the wire nor less than 4 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

4.3.5 The welding conditions (amperage, voltage and rate of travel) are to be in accordance with the recommendations of the manufacturer and are to conform with normal good welding practice for multi-run welding.

4.3.6 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.3.7 Two longitudinal tensile and three impact test specimens are to be taken from each test assembly as shown in Fig. 11.4.1. Care is to be taken that the axes of the tensile test specimens coincide with the centre of the weld and the mid-thickness of the plates. The impact test specimens are to be cut perpendicular to the weld with their axes 10 mm from the upper surface. The notch is to be positioned in the centre of the weld and cut in the face of the test specimen perpendicular to the surface of the plate.

4.3.8 In those cases where two-run technique approval is also sought, only one longitudinal tensile specimen need be prepared and tested from this assembly.

4.3.9 The results of all tests are to comply with the requirements of Table 11.4.2, as appropriate.

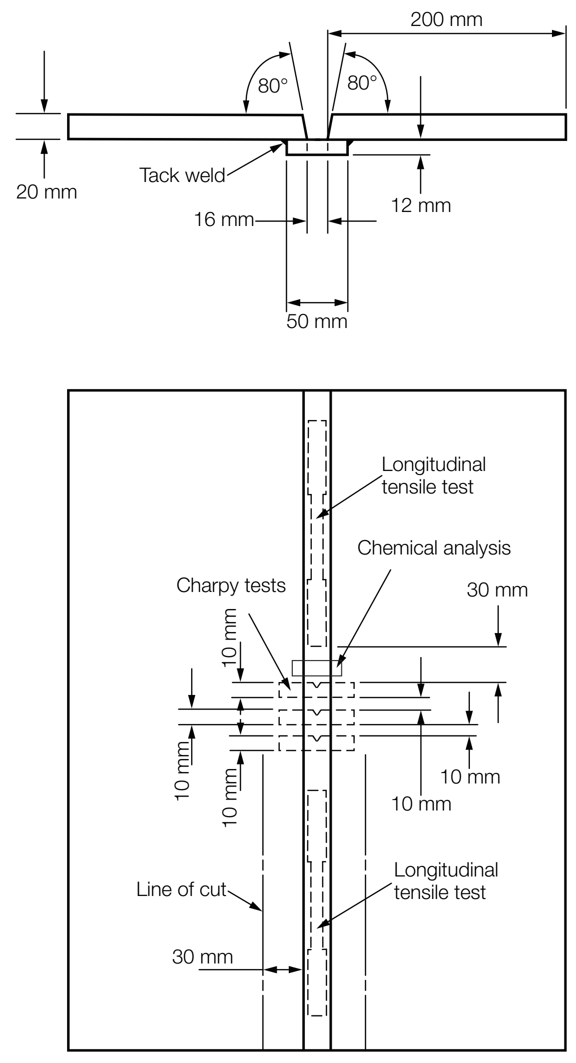


Fig. 11.4.1 Deposited metal test assembly

4.4 Butt weld test assemblies (multi-run technique)

4.4.1 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2.

4.4.2 The grade of steel used for the preparation of the test assembly are to be as follows:

Grade 1 wire-flux combination	A
Grade 2 wire-flux combinations	A, B or D
Grade 3 wire-flux combinations	A, B, D or E
Grade 1Y wire-flux combination	AH32 or AH36
Grade 2Y wire-flux combinations	AH32, AH36, DH32 or DH36
Grade 3Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32 or EH36
Grade 4Y wire-flux combinations	AH32, AH36, DH32, DH36, EH32, EH36, FH32 or FH36
Grade 2Y40 wire-flux combination	AH40 or DH40

Table 11.4.2 Requirements for deposited metal tests (wire-flux combinations)

Grade	Yield stress N/mm² minimum	Tensile strength N/mm²	Elongation on 50 mm % minimum	Charpy V-notch impact tests	
				Test temperature °C	Average energy (*see* Note) J minimum
1N, 2N, 3N	305	400 – 560	22	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	375	490 – 660	22	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	400	510 – 690	22	0, –20, –40, –60	39
2Y47, 3Y47, 4Y47	460	570 – 720	19	0, –20, –40	53
3Y40	400	510 – 690	22	–20	39
3Y42	420	530 – 680	20	–20	47
3Y46	460	570 – 720	20	–20	47
3Y50	500	610 – 770	18	–20	50
3Y55	550	670 – 830	18	–20	55
3Y62	620	720 – 890	18	–20	62
3Y69	690	770 – 940	17	–20	69
4Y40	400	510 – 690	22	–40	39
4Y42	420	530 – 680	20	–40	47
4Y46	460	570 – 720	20	–40	47
4Y50	500	610 – 770	18	–40	50
4Y55	550	670 – 830	18	–40	55
4Y62	620	720 – 890	18	–40	62
4Y69	690	770 – 940	17	–40	69
5Y40	400	510 –690	22	–60	39
5Y42	420	530 – 680	20	–60	47
5Y46	460	570 – 720	20	–60	47
5Y50	500	610 – 770	18	–60	50
5Y55	550	670 – 830	18	–60	55
5Y62	620	720 – 890	18	–60	62
5Y69	690	770 – 940	17	–60	69
1½ Ni	375	460	22	–80	34
3½ Ni	375	420	25	–100	34
5 Ni	375	500	25	–120	34
9 Ni	375	600	25	–196	34

NOTE
Energy values from individual impact test specimens are to comply with 1.4.3.

Grade 3Y40 wire-flux combinations	AH40, DH40 or EH40
Grade 4Y40 wire-flux combinations	AH40, DH40, EH40 or FH40
Grade 5Y40 wire-flux combinations	AH40, DH40 EH40, FH40
Grade 2Y47 wire-flux combinations	AH47 or DH47
Grade 3Y47 wire-flux combinations	AH47, DH47 or EH47
Grade 4Y47 wire-flux combinations	AH47, DH47, EH47 or FH47

Where Grade 32 higher tensile steel is used, the tensile strength is to be not less than 490 N/mm². The chemical composition, including the content of grain refining elements, is to be reported in all cases where higher tensile steel is used.

4.4.3 For all other grades, the steel plates used are to be selected by reference to Table 11.1.1, and are to have at least their chemical composition and tensile properties within the limits specified for that grade in Chapter 3. The strength grade used is to be the same as that for which approval is sought, and the toughness grade is to be no higher than that for which approval is also sought.

4.4.4 The plate edges are to be prepared to form a single V-joint, the included angle between the fusion faces being 60° and the root face being 4 mm. The bevelling of the plate edges is to be carried out by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from bevelled edges.

4.4.5 Welding is to be carried out in the downhand position by the multi-run technique, and the welding conditions are to be the same as those adopted for the deposited metal test assembly. The back sealing run is to be applied in the downhand position after cutting out the root run to clean metal.

Table 11.4.3 Requirements for butt weld tests (wire-flux combinations)

Grade	Tensile strength N/mm^2	Bend test ratio: $\frac{D}{t}$	Charpy V-notch impact tests	
			Test temperature °C	Average energy (*see* Notes 1 and 2) J minimum
1N, 2N, 3N	400	3	+20, 0, –20	34
1Y, 2Y, 3Y, 4Y	490	3	+20, 0, –20, –40	34
2Y40, 3Y40, 4Y40, 5Y40	510	3	0, –20, –40, –60	39
2Y47, 3Y47, 4Y47	570 – 720	4	0, –20, –40	53
3Y40	510	3	–20	39
3Y42	530 – 680	4	–20	47 (41)
3Y46	570 – 720	4	–20	47
3Y50	610 – 770	4	–20	50
3Y55	670 – 830	5	–20	55
3Y62	720 – 890	5	–20	62
3Y69	770 – 940	5	–20	69
4Y40	510	3	–40	39
4Y42	530 – 680	4	–40	47 (41)
4Y46	570 – 720	4	–40	47
4Y50	610 – 770	4	–40	50
4Y55	670 – 830	5	–40	55
4Y62	720 – 890	5	–40	62
4Y69	770 – 940	5	–40	69
5Y40	510	3	–60	39
5Y42	530 – 680	4	–60	47 (41)
5Y46	570 – 720	4	–60	47
5Y50	610 – 770	4	–60	50
5Y55	670 – 830	5	–60	55
5Y62	720 – 890	5	–60	62
5Y69	770 – 940	5	–60	69
1½ Ni	490	3	–80	27
3½ Ni	450	3	–100	27
5 Ni	540	4	–120	27
9 Ni	640	4	–196	27

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Values in ( ) apply only to two-run technique impact test specimens.

4.4.6 It is recommended that the welded assembly be subjected to a radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.4.7 The test specimens as shown in Fig. 11.3.3 and Fig. 11.4.2 are to be prepared from each test assembly.

4.4.8 The results of all tensile and impact tests are to comply with the requirements of Table 11.4.3, as appropriate. The position of fracture of the transverse tensile test is to be reported.

4.4.9 The bend test specimens can be considered as complying with the requirements if, after bending, no cracks or other open defects exceeding 3 mm in dimension can be seen on the outer surface.

4.5 Approval tests for two-run technique

4.5.1 Where approval for use with the two-run technique is requested, two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

4.5.2 Two welded assemblies are to be made from a pair of plates of matching thicknesses. The thickness of the thicker pair of plates will be the maximum for which the approval is valid. The second assembly is to be welded from plates having approximately half of the thickness of the first assembly.

4.6 Butt weld test assemblies (two-run technique)

4.6.1 The grade of steel used for the preparation of the test assemblies is not to be of any higher grade (impact toughness) than that for which approval is required. The chemical composition, including the content of grain refining elements, and the strength properties of the plates used, are to be reported.

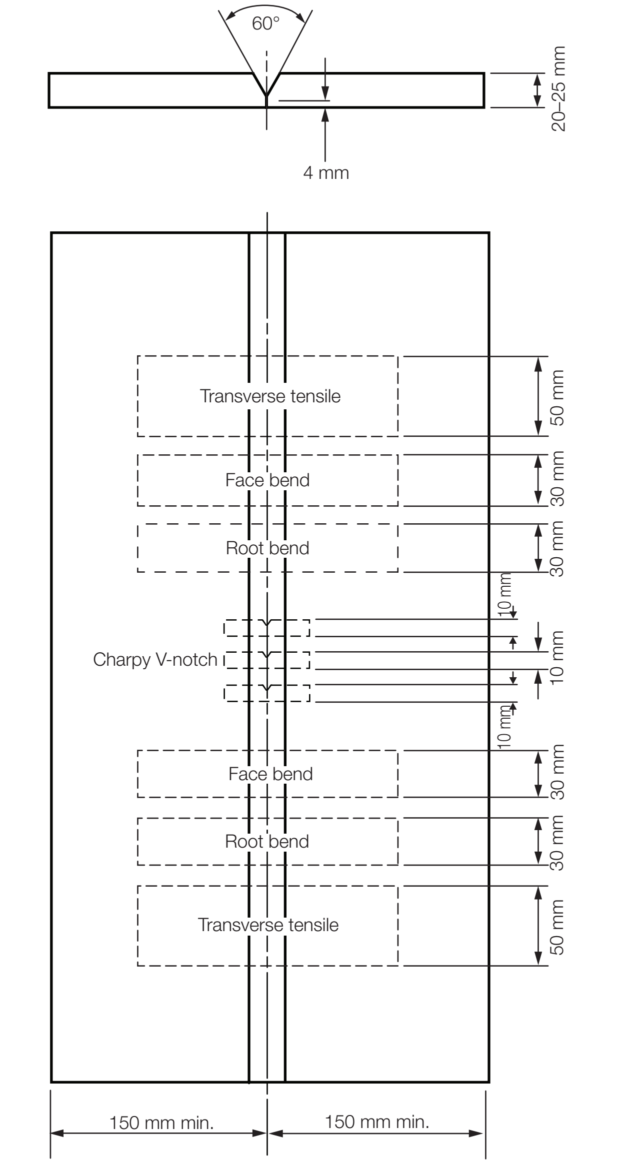


Fig. 11.4.2
Butt weld test assembly (multi-run technique)

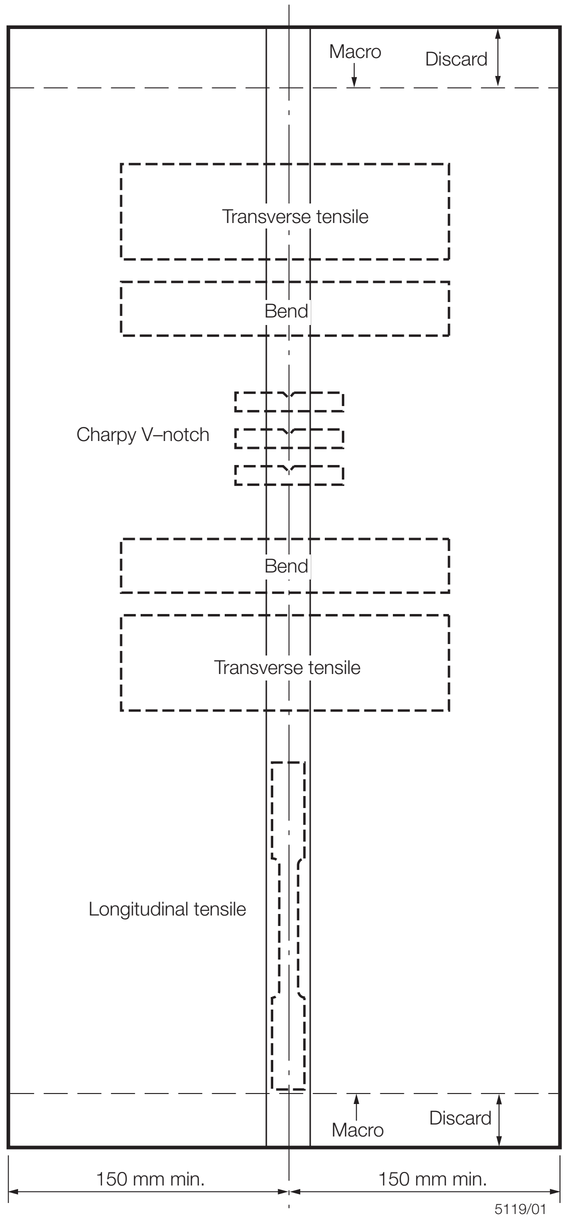


Fig. 11.4.3
Butt weld test assembly (two-run technique)

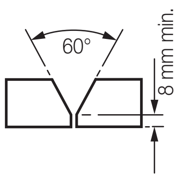
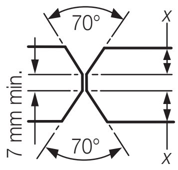
4.6.2 The maximum diameter of wire and the edge preparation to be used are to be in accordance with Table 11.4.4. Small deviations in the edge preparation may be allowed if requested by the manufacturer. The bevelling of the plate edges is to be performed by machining or mechanised gas cutting. In the latter case, any remaining scale is to be removed from the bevelled edges. The root gap should not exceed 0,7 mm.

4.6.3 Each butt weld is to be welded in two runs, one from each side, using amperages, voltages and travel speeds in accordance with the recommendations of the manufacturer and normal good welding practice. After completion of the first run, the flux and welding slag are to be removed and the assembly is to be left in still air until it has cooled to less than 100°C, the temperature being taken in the centre of the weld, on the surface of the seam.

4.6.4 It is recommended that the butt weld assemblies be subjected to radiographic examination to ascertain if there are any defects in the weld prior to the preparation of test specimens.

4.6.5 The test specimens, as shown in Fig. 11.4.3 and Fig. 11.4.4, are to be prepared from each test assembly, except as detailed in 4.6.8. The edges of two of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. At each cut in the test assembly, the edges are also to be examined to ensure that complete fusion has taken place.

Table 11.4.4 Butt weld assembly preparation

Plate thickness mm	Recommended diameter	Maximum diameter of wire mm
12,5		5
20–25		6
35–40		7

4.6.6 The results of transverse tensile and impact tests are to comply with the requirements of Table 11.4.3 as appropriate. The position of fracture of the transverse tensile tests is to be reported.

4.6.7 The bend test specimens can be considered as complying with the requirements if, after bending, no crack or other open defects exceeding 3 mm in dimensions can be seen on the outer surface. One of the specimens from each assembly is to be tested with the side first welded in tension, and the second specimen with the other side in tension.

4.6.8 The longitudinal tensile specimen shown in Fig. 11.4.3 is to be prepared from the thicker assembly, even in those cases where multi-run technique approval is also sought. This test specimen is to be machined to the dimensions shown in Ch 11,2.1.1, and the longitudinal axis is to coincide with the centre of the weld about 7 mm below the plate surface on the side from which the second run is made. The test specimen may be given a hydrogen release treatment in accordance with 2.1.1. The results of this test are to comply with the requirements of Table 11.4.2.

4.6.9 The chemical analysis of the weld metal of the second run in each assembly is to be determined and reported. This is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

4.7 Annual tests

4.7.1 Annual tests are to consist of at least the following:

(a) For wire-flux combinations approved for the multi-run technique, one deposited metal test assembly.

(b) For wire-flux combinations approved for the two-run technique, one butt weld test assembly using plate material 20 to 25 mm in thickness. For Y47 the thickness of plate material may be taken as 50 mm.

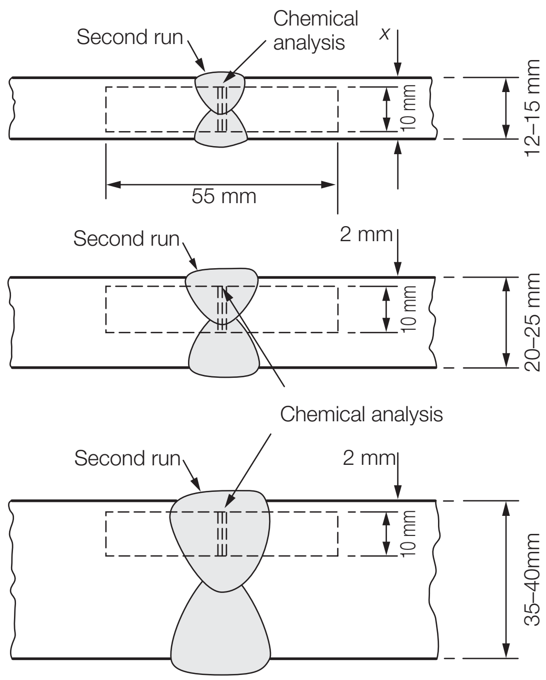


Fig. 11.4.4
Butt weld test assembly (two-run technique): position of impact test specimens

4.7.2 The deposited metal assemblies are to be prepared and tested in accordance with 4.3, except that only one longitudinal tensile, three impact test specimens and a chemical analysis are required.

4.7.3 The butt weld test assemblies are to be prepared and tested in accordance with 4.6, except that only one transverse tensile, two bend, three impact test specimens and a chemical analysis are required. One longitudinal tensile test specimen is also to be prepared where the wire-flux combination is approved solely for the two-run technique.

4.7.4 Where a wire-flux combination is approved for welding a range of steels with different specified minimum strength levels, steel of the highest strength approved is to be used for the preparation of the butt weld assembly required by 4.7.1(b).

■ *Section 5*
Wires and wire-gas combinations for manual, semi-automatic and automatic welding

5.1 General

5.1.1 Wire-gas combinations and flux-cored or flux-coated wires (for use with or without a shielding gas) are divided into the following categories for the purposes of approval testing:

(a) For use in manual multi-run welding with the inert gas tungsten arc welding process (GTAW).

Table 11.5.1 Minimum low hydrogen approval requirements for wires and wire-gas combinations

Approval grade	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for T technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (see Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
2Y47 to 4Y47	H10	H10	H10
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^1/_2$ Ni	H15	H15	NR
$3^1/_2$ Ni	H15	H15	NR
5 Ni	NR (see Note 3)	NR	NR
9 Ni	NR (see Note 3)	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes use of an austenitic, non-transformable, filler material.

(b) For use in semi-automatic multi-run metal arc welding.
(c) For use in single electrode multi-run automatic metal arc and GTAW welding.
(d) For use in single electrode two-run automatic metal arc and GTAW welding.

5.1.2 The term 'manual', is used to describe the technique where the gas-shielded tungsten arc torch is held in one hand and the filler is added separately by the other hand.

5.1.3 The term 'semi-automatic' is used to describe processes in which the weld is made manually by a welder holding a gun through which the wire is continuously fed.

5.1.4 In the GTAW process, 'automatic' refers to the fully mechanised control and application of both torch and separate filler wire.

5.1.5 Dependent on the results of mechanical and other tests, approval will be allocated as one of the grades from Table 11.1.1.

5.1.6 A suffix S will be added after the grade mark to indicate approval for semi-automatic multi-run welding.

5.1.7 For wires intended for automatic welding, the suffixes T or M will be added after the grade mark to indicate approval for two-run or multi-run welding techniques, respectively.

5.1.8 For wires intended for both semi-automatic and automatic welding, the suffices will be added in combination.

5.1.9 Solid wire-gas combinations are considered naturally low hydrogen in character and qualify for 'H15' approval without testing. This is not so for cored wires and continuous coated wires which must be tested if there is a need for low hydrogen approval. For the lower strength grades of steel, low hydrogen testing is not normally a requirement for approval. With higher strength steels, it is more important and Table 11.5.1 shows the mandatory minimum low hydrogen status required for approval of wire-gas combinations.

5.1.10 The testing methods to be used for low hydrogen approval are to be in accordance with 3.4, modified to use the manufacturer's recommended welding conditions and adjusting the deposition rate to give a weld deposit weight per sample similar to that deposited when using manual electrodes.

5.1.11 Where applicable, the approved combination will name either the specific gas composition or its trade name, but in either case the composition of the shielding gas is to be reported. Unless otherwise agreed, additional approval tests are required when a shielding gas is used other than that used for the original approval tests. However a wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

5.1.12 Wires and wire-gas combinations for multiple electrode automatic welding will be subject to separate approval tests. Any proposals are to be submitted for consideration.

5.1.13 Wires and wire-gas combinations approved with multi-run technique for normal and higher strength levels up to and including 'Y' are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

5.1.14 Wires and wire-gas combinations approved with multi-run technique for strength levels Y40 to Y50, but excluding Y47 are also considered suitable for welding steels in two strength levels below that for which they have been approved.

5.1.15 Wires and wire-gas combinations approved with multi-run technique for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

5.1.16 Wires and wire-gas combinations with two-run technique approval are not considered suitable for welding steels of any other strength level with that technique, *see* 5.4.1.

5.2 Approval tests for manual and semi-automatic multi-run welding

5.2.1 Approval tests for manual (GTAW) and semi-automatic multi-run welding are to be carried out generally in accordance with the requirements of Section 3, except as required by 5.2, using the respective technique for the preparation of all test assemblies.

5.2.2 Two deposited metal test assemblies are to be prepared in the downhand position as shown in Fig. 11.3.1, one using the smallest diameter, and the other using the largest diameter of wire for which approval is required. Where only one diameter is manufactured, only one deposited metal assembly is to be prepared.

5.2.3 For Y47 grades, as an alternative to Figs. 11.3.1 to 11.3.4, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.2.4 The weld metal is to be deposited according to the practice recommended by the manufacturer, and the thickness of each layer of weld metal is to be between 2 mm and 6 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.2.5 The chemical analysis of the deposited weld metal in each test assembly is to be supplied by the manufacturer and is to include the content of all significant alloying elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.2.6 Butt weld assemblies as shown in Fig. 11.3.2 are to be prepared for each welding position for which the wire is to be approved. In the case of approvals for normal and higher strength steels (up to 355 N/mm^2 minimum specified yield strength), tests satisfying the requirements in both the downhand and vertical-upward positions will be considered as having also satisfied the requirements for the horizontal-vertical position. In all other cases, approval in the horizontal-vertical position will require a butt weld to be made in that position and be fully tested.

5.2.7 The downhand assembly is to be welded using, for the first run, wire of the smallest diameter to be approved and, for the remaining runs, wire of the largest diameter to be approved.

5.2.8 Where approval is requested only in the downhand position, an additional butt weld assembly is to be prepared in that position using, if possible, wires of different diameter from those required by 5.2.7. If only one wire diameter is to be approved, this second downhand butt weld should be made using either larger or smaller beads than the first assembly.

5.2.9 The butt weld assemblies, in positions other than downhand, are to be welded using, for the first run, wire of the smallest diameter to be approved, and for the remaining runs, the largest diameter of wire recommended by the manufacturer for the position concerned.

5.2.10 Fillet weld test assemblies as detailed in 3.5 are to be prepared, examined and tested.

5.2.11 Low hydrogen approval tests are to be carried out if required by 5.1.9.

5.2.12 Test specimens from each assembly are to be prepared and tested in accordance with the requirements of 3.2 and 3.3.

5.3 Approval tests for multi-run automatic welding

5.3.1 Approval tests for multi-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.3, using the multi-run automatic welding technique for the preparation of all test assemblies.

5.3.2 One deposited metal test assembly is to be prepared as shown in Fig. 11.4.1. Welding is to be as detailed in 4.3.4, except that the thickness of each layer is to be not less than 3 mm, unless it is clearly stated as part of the consumable manufacturer's published recommendations.

5.3.3 For Y47 grades, as an alternative to Figs. 11.4.1 and 11.4.2, the thickness of the plate used for the test assembly may be taken as 50 mm.

5.3.4 One butt weld test assembly is to be prepared as shown in Fig. 11.4.2 for each welding position to be approved for the automatic multi-run technique.

5.3.5 Test specimens from each test assembly are to be prepared and tested in accordance with the requirements of Section 4 for multi-run submerged-arc automatic welding.

5.3.6 Low hydrogen approval tests are to be made if required by 5.1.9.

5.3.7 At the discretion of LR, wires approved for semi-automatic welding in the downhand position may also be approved without additional tests, for use in multi-run automatic welding.

5.4 Approval tests for two-run automatic welding

5.4.1 Approval tests for two-run automatic welding are to be carried out generally in accordance with the requirements of Section 4, except as required by 5.4, using the two-run automatic welding technique for the preparation of all test assemblies. Two butt weld test assemblies are to be prepared and tested using plates of the strength level for which approval is required. Each strength level requires separate approval.

5.4.2 Two butt weld test assemblies are to be prepared generally as detailed in 4.5 and 4.6 using plates 12 to 15 mm and 20 to 25 mm in thickness.

5.4.3 If approval is requested for welding plate thicker than 25 mm, one assembly is to be prepared using plates approximately 20 mm in thickness and the other using plates of the maximum thickness for which approval is requested.

5.4.4 The edge preparation of the test assemblies is to be as shown in Fig. 11.5.1. Small deviations in edge preparation may be allowed, if these form part of the consumable manufacturer's recommendations. For assemblies using plates over 25 mm in thickness, the edge preparation is to be reported for information.

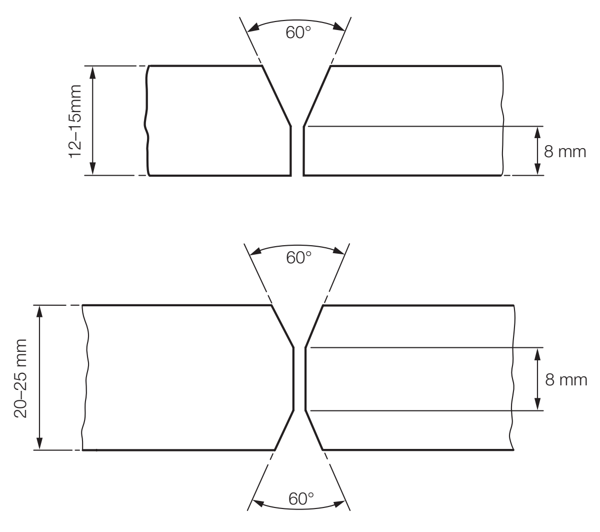


Fig. 11.5.1
Normal edge preparation for two-run butt weld test assemblies

5.4.5 The diameters of wires used are to be in accordance with the recommendations of the manufacturer and are to be reported.

5.4.6 Test specimens from each butt weld assembly are to be prepared and tested in accordance with the requirements of Section 4 for two-run submerged-arc automatic welding.

5.4.7 The weld metal chemical analysis is to be reported as in 4.6.9. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

5.5 Annual tests

5.5.1 Annual tests are to consist of at least the following:

(a) Wires approved for manual welding or semi-automatic welding or either of these combined with approval for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.2 using a wire of diameter within the approved range.

(b) Wire approved for automatic multi-run welding:
one deposited metal test assembly prepared in accordance with 5.3 using a wire of diameter as stated in (a).

(c) Wires approved for two-run automatic welding:
one butt weld test assembly prepared in accordance with 5.4 using plates 20 to 25 mm in thickness or the maximum approved thickness. The diameter of wire used is to be reported.

■ *Section 6*
Consumables for use in electro-slag and electro-gas welding

6.1 General

6.1.1 The requirements for the approval of consumables used for electro-slag or electro-gas welding (including consumable nozzles, where applicable) are generally as detailed in Section 4 for two-run submerged-arc welding consumables, except as otherwise detailed in this Section.

6.1.2 For each grade, approval may be restricted for use with specific compositional types of steel. For Grades 1Y, 2Y, 3Y, 4Y, 2Y40, 3Y40 and 4Y40 this will normally be in respect of the grain refining element content, and tests on niobium grain refined steel will normally qualify for use also on steels treated with aluminium or vanadium or combinations of these elements.

6.1.3 Superscript numbers are applied to the 'Y' of higher strength steel consumables, e.g. $2Y^1$, to indicate the type of parent steel for which approval is applicable as follows:

Y^1 approval Grade for higher strength steel is limited to parent steel which has been treated only with aluminium.

Y^2 approval Grade for higher strength steel is appropriate to niobium-treated steels, whether aluminium treated or not. It also covers steels treated only with aluminium.

6.1.4 Each strength level requires separate approval involving the welding and testing of two butt weld assemblies of different thickness. The greater thickness will determine the maximum approved thickness.

6.2 Butt weld test assemblies

6.2.1 Two butt weld test assemblies are to be prepared, one with plates 20 to 25 mm in thickness and the other with plates 35 to 40 mm in thickness. The steel used is not to be of any higher grade (impact toughness) than that for which approval is required. The limitations of 6.1.2 need to be considered in this Section. The chemical composition of the plate, including the content of grain refining elements, is to be reported.

6.2.2 The welding conditions and the edge preparation adopted are to be in accordance with the recommendations of the manufacturer and are to be reported in detail. The manufacturer's maximum recommended gap between plates is to be used in making the test assemblies.

6.2.3 It is recommended that the assemblies are subjected to radiographic examination to identify any defects before the preparation of any test specimens.

6.2.4 Test specimens as follows, and as shown in Fig. 11.6.1, are to be prepared from each test assembly:
(a) Two longitudinal tensile test specimens.
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) Two macro-sections.
(e) Two sets of three impact test specimens notched in accordance with Fig. 11.6.2.

6.2.5 The chemical analysis of the weld metal in each assembly is to be determined and reported. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

6.2.6 The results of all transverse tensile and impact tests are to comply with the requirements given in Table 11.4.3 as appropriate. The position of fracture of the transverse tensile test is to be reported. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

6.2.7 The results of all longitudinal tensile tests are to comply with the requirements of Table 11.4.2.

6.2.8 The bend test specimens are to be in accordance with 4.6.7 and Table 11.4.3. Each surface of the weld is to be tested Fension.

6.3 Annual tests

6.3.1 Annual tests are to consist of at least one butt weld test assembly using plate material 20 to 25 mm in thickness.

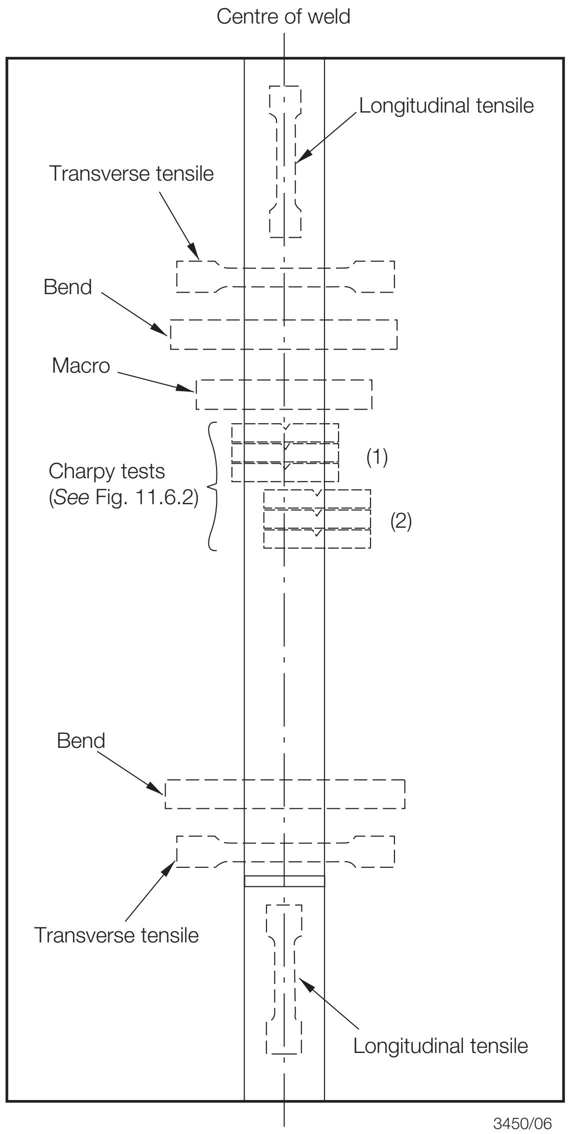


Fig. 11.6.1
Butt weld test assembly for electro-slag or electro-gas welding

6.3.2 The assembly is to be prepared and tested in accordance with 6.2 except that only the following tests are required:

(a) One longitudinal tensile test.
(b) One transverse tensile test.
(c) Two bend tests.
(d) Two sets of three Charpy V-notch impact tests; one set with the notch at the centre of the weld (Position (1) in Fig. 11.6.2), and one set with the notch in the weld metal 2 mm from the fusion line (Position (2) in Fig.11.6.2).
(e) Chemical analysis.
(f) One macro section.

6.3.3 Where a consumable or combination is approved for a range of steels with different specified minimum strength levels, steel of the highest strength level is to be used for the preparation for the assembly required by 6.3.1.

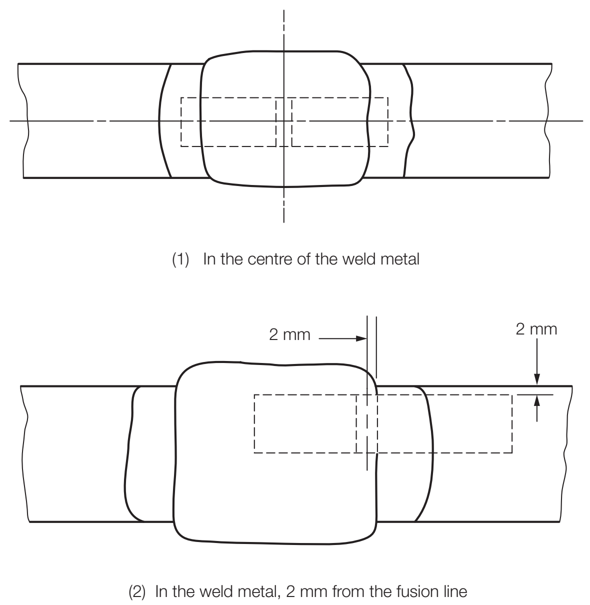


Fig. 11.6.2
Position of Charpy V-notch impact test specimens

Section 7
Consumables for use in one-side welding with temporary backing materials

7.1 General

7.1.1 The requirements for approval of combinations including temporary backing material, for use in one-side welding techniques, are dependent on the technique used and which basic technique it most closely follows. The following are provided for:
(a) Technique m – for manual electrode/backing combinations.
(b) Technique S – for wire-gas/backing combinations used with semi-automatic multi-run technique.
(c) Technique M – for wire-flux or wire-gas in combination with backing material (and maybe supplementary filler materials) used with an automatic multi-run technique.
(d) Technique A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

7.1.2 For technique m, S or M, a single butt weld is to be made in plate of 20–25 mm thickness. For technique A, two butt welds are to be made, one in plate of the maximum thickness recommended by the manufacturer, the other in plate of approximately half the thickness of the first. Usually this will involve thicknesses in the region of 35–40 mm and 20–25 mm respectively.

7.1.3 A wire and gas combination approved with an argon/carbon dioxide shielding gas where the carbon dioxide content is between 15-25 per cent is also approved for other combinations of argon/carbon dioxide, provided the carbon dioxide content is within the range 15-25 per cent. The range of approval is limited to ferritic consumables in solid wire, flux cored and coated wire forms and subject to the agreement of the consumable manufacturer and LR.

7.1.4 Any unrecognised techniques or unusual combinations will be considered for approval subject to a test programme to be agreed based on the details of the technique and combination which are to be submitted in advance.

7.1.5 Where low hydrogen approval is required either by Table 11.7.1 or by the manufacturer, it should be noted that this will generally be achieved through separate testing of:
(a) the backing material, and
(b) the welding electrode or combination of wire-flux or wire-gas.

7.1.6 The hydrogen potential of the backing material is to be determined using the modified Gayley-Wooding method which expresses the total hydrogen content as water by weight per cent. The qualifying levels are:

To qualify as:	H_20 g/100g sample
H15	0,5
H10	0,3
H5	0,2

7.1.7 The sampling and approval of the combinations without the backing are to follow the general requirements of Sections 3, 4 or 5, as appropriate.

7.1.8 Combinations approved with multi-run technique (m, S and M) for normal and higher strength levels up to and including ‘Y’ are also considered suitable for welding steels in the three strength levels below that for which they have been approved.

7.1.9 Combinations approved with multi-run technique (m, S and M) for strength levels Y40 to Y50, but excluding Y47, are also considered suitable for welding steels in two strength levels below that for which they have been approved.

7.1.10 Combinations approved with multi-run technique (m, S and M) for strength levels Y47, Y55 and above are also considered suitable for welding steels in only one strength level below that for which they have been approved.

7.1.11 Combinations approved for the ‘A’ multi-run technique are not considered suitable for welding steels of any other strength level with that technique.

Table 11.7.1 Minimum low hydrogen approval requirements for one-side welding with combinations including temporary backing material

Approval grades	'H' grade for m and S techniques	'H' grade for M technique	'H' grade for A technique
1 (1N), 2 (2N), 3 (3N)	NR	NR	NR
1Y, 2Y, 3Y, 4Y	H15 (*see* Note 2)	NR	NR
2Y40 to 5Y40	H15	H15	NR
2Y47 to 4Y47	H10	H10	H15
3Y42 to 5Y42	H10	H10	H15
3Y46 to 5Y46	H10	H10	H15
3Y50 to 5Y50	H10	H10	H10
3Y55 to 5Y55	H5	H5	H10
3Y62 to 5Y62	H5	H5	H5
3Y69 to 5Y69	H5	H5	H5
$1^{1}/_{2}$ Ni	H15	H15	NR
$3^{1}/_{2}$ Ni	H15	H15	NR
5 Ni (*see* Note 3)	NR	NR	NR
9 Ni (*see* Note 3)	NR	NR	NR

NOTES
1. NR – Not required. Approval may be obtained when requested.
2. Optional in this case. If low hydrogen approval is not obtained, there is a limitation on the carbon equivalent of the steel which is permitted to be welded.
3. Assumes the use of an austenitic, non-transformable, filler material.

7.2 Approval tests for manual (m), semi-automatic (S) and automatic multi-run (M) techniques

7.2.1 For each position to be approved, one butt weld assembly is to be prepared using plates of 20–25 mm thickness as shown in Fig. 11.7.1. The grade of plate used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

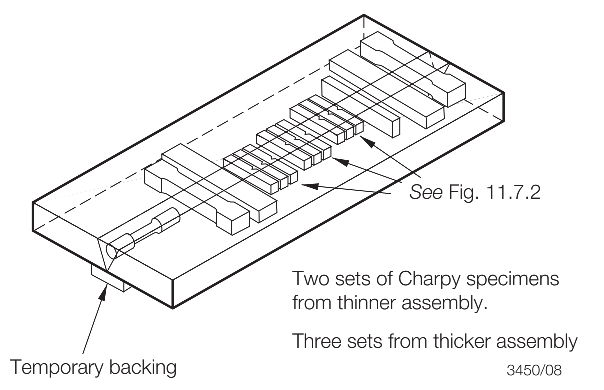


Fig. 11.7.1
Butt weld test assembly and specimens for all techniques

7.2.2 The thickness of test assembly is to be 50 mm for Y47 base material.

7.2.3 The edge preparation and welding conditions are to be in accordance with the recommendations of the manufacturers.

7.2.4 Test specimens are to be prepared as shown in Fig. 11.7.1 and Fig. 11.7.2(a):
(a) One longitudinal tensile test specimen (from the centre of the weld).
(b) Two transverse tensile specimens.
(c) Two bend test specimens, one with the face in tension, the other with the root in tension.
(d) One macrosection.
(e) Two sets of three Charpy impact test specimens positioned and notched in accordance with Fig.11.7.2(a).

7.2.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements in Table 11.3.3 for m and S technique, and Table 11.4.3 for M technique. The position of fracture of the transverse tensile test is to be reported. The appearance of the bend test specimens is to be in accordance with 3.3.13.

7.2.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2.

7.2.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.2.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the upper and lower Charpy specimens of the downhand butt weld. These are to be supplied by the manufacturer and are to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

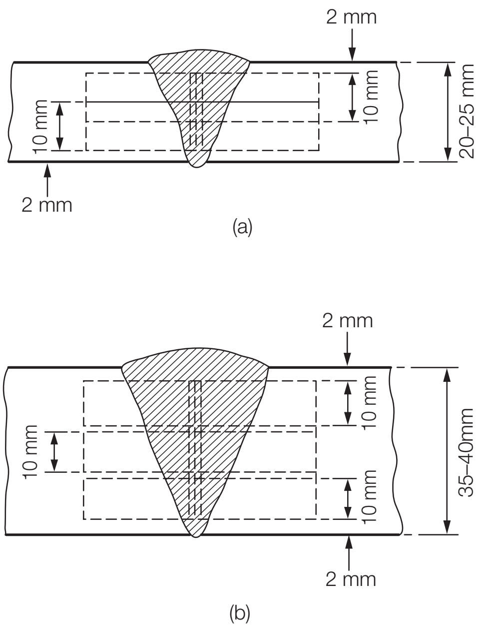


Fig. 11.7.2
Position of Charpy V-notch impact tests for one-side automatic welding

7.3 Approval tests for high heat input automatic (A) techniques

7.3.1 Two butt weld assemblies are to be prepared, usually one of 35–40 mm thickness, the other 20–25 mm, as shown in Fig. 11.7.1, noting that in the thinner assembly only two sets of Charpy specimens are required. The grade of plates used is to be no higher in toughness than that for which approval is required. The strength is to be appropriate to the grade for which welding approval is requested.

7.3.2 For Y47 grade, the thicker assembly is to be prepared from the maximum thickness for which approval is required, and the thinner assembly is to be prepared from 50 mm thickness. Where approval is required for 50 mm thickness, only one assembly from that thickness is required.

7.3.3 The edge preparation and welding conditions are to be in accordance with the manufacturer's recommendations, and are to be reported to LR.

7.3.4 Test specimens as follows are to be prepared as shown in Fig. 11.7.1 and Figs. 11.7.2(a) and (b):
(a) One longitudinal tensile test specimen (from centre of weld).
(b) Two transverse tensile test specimens.
(c) Two bend test specimens.
(d) One macro-section.
(e) From assembly 20 to 25 mm thick, two sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(a).
(f) From assembly 35 to 40 mm thick, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b).
(g) From assembly of thickness 50 mm or more, three sets of three impact test specimens positioned and notched in accordance with Fig. 11.7.2(b). The second set positioned in the mid-thickness of test assembly.
The bend specimens are to be tested, one with the face in tension, the other with the root in tension.

7.3.5 The results of all transverse tensile, bend and impact tests are to comply with the requirements of Table 11.4.3. The appearance of the bend test specimens is to be in accordance with 3.3.13. The Charpy V-notch impact test requirements are as for the two-run technique in Table 11.4.3.

7.3.6 The results of all longitudinal tensile tests are to comply with the requirements in Table 11.3.2, except that for Grades 1Y, 2Y and 3Y the tensile strength is to be not less than 490 N/mm^2.

7.3.7 Low hydrogen approval is required in accordance with Table 11.7.1.

7.3.8 Chemical analyses are to be made and reported from positions corresponding to the weld metal in the uppermost and lowest Charpy specimens in the thicker plate weld. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

7.4 Annual tests

7.4.1 Annual tests are to consist of, at least, one butt weld test assembly, for each technique approved, using plates of 20 to 25 mm thickness.

7.4.2 The assembly is to be prepared and tested in accordance with 7.2 or 7.3, as appropriate, except that only the following tests are required:
(a) One longitudinal tensile test (from centre of weld).
(b) One transverse tensile test.
(c) Two bend tests.
(d) One set of three impact tests taken from the root of the weld and the specimens notched in accordance with Fig. 11.7.2.
(e) Chemical analysis (one only).

■ *Section 8* Consumables for welding austenitic and duplex stainless steels

8.1 General

8.1.1 Tests for the approval of consumables intended for welding the austenitic and duplex stainless steels detailed in Ch 3,7 are to be carried out generally in accordance with the Section (3, 4, 5, 6 or 7) relevant to the type of consumable or combination.

8.1.2 Approval will be indicated by the grade or grades of parent stainless steel for which the consumable or combination is approved.

8.1.3 Where a shielding gas is employed, separate approval will be required for each specific shielding gas composition.

8.1.4 Consumables for welding the austenitic stainless steels and the duplex stainless steels to carbon or carbon-manganese steels will be approved in a similar manner. Parent plate used for the butt and fillet weld test assemblies will be carbon or carbon-manganese steel with either austenitic stainless steel or duplex stainless steel, as appropriate. Approval will be indicated by 'SS/CMn' and 'Dup/CMn' respectively, however, no buttering of test assembly plates is allowed for these two approvals.

8.1.5 Separate approval will be given for welding chemical and cryogenic applications. For chemical use, evidence of relevant corrosion resistance will be required. Charpy impact toughness tests will be required for all uses, but for cryogenic use the Charpy impact toughness requirements are more severe.

8.1.6 The welding technique will be indicated in the approval grading by a letter:

- m – for manual SMAW or GTAW welding.
- S – for wire-gas combinations used with a semi-automatic multi-run technique.
- M – for wire-flux or wire-gas combinations used with an automatic multi-run technique.
- T – for wire-flux or wire-gas combinations used with an automatic two-run technique.
- A – as for M but using a procedure with a high heat input rate (large bead size relative to thickness welded). This would apply to welds made by four or less runs in 20 mm thickness, or eight or less runs in 35 mm.

8.2 Deposited metal test assemblies

8.2.1 Where the relevant Section requires deposited metal assemblies to be made and tested, the plates used must be either of the type for which approval is required or of normal strength carbon, or carbon-manganese steel with the prepared edges built up with stainless steel weld metal and finished with a layer of weld metal from the consumable to be approved.

8.2.2 The chemical analysis of the deposited weld metal is to be reported, including all significant elements. The elements reported will be dependent on the type of stainless steel for which approval of the consumables is requested. Any unusual weld metal compositions will have to be justified in respect of the particular approval requested. This is to be supplied by the manufacturer and is to include the content of all significant elements. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

8.2.3 The results of all tensile and notch impact tests are to comply with the requirements given in Table 11.8.1 as appropriate.

8.2.4 The ferrite content in the last weld run from each deposited metal assembly is to be determined by physical or metallographic means, and reported, indicating the method of determination.

8.3 Butt weld test assemblies

8.3.1 Where the relevant Section requires butt weld assemblies to be made and tested, the plates used are to be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, provided the consumable is metallurgically compatible with the base material to be used, the prepared edges are to be built up with a layer of weld metal before final machining of the weld preparation.

8.3.2 The results of transverse tensile, notch impact and bend tests are to comply with the requirements of Table 11.8.2 as appropriate. The position of fracture is to be reported to LR.

8.3.3 The ferrite content at the centre of the weld metal in each butt weld assembly is to be determined by physical or metallographic means, and meet the requirements in Table 11.8.2. The method of determination is to be reported.

8.3.4 For austenitic and duplex stainless steel approvals (except for types 304L, 316L, 321 and 347), an appropriate sample from each butt weld assembly is to be submitted to the corrosion testing provided in ASTM G48, Method 'C'. The results are to be reported so as to allow confirmation of the maximum acceptable pitting corrosion resistance temperature. This will be part of the approval grading and will be set at 5°C intervals. The minimum pitting corrosion temperature would not be expected to be less than 20°C.

8.4 Fillet weld test assemblies

8.4.1 Where the relevant Section requires fillet weld assemblies to be made and tested, the plates used must be either of the type for which approval is required or of steel having strength and ductility within the range specified for the grade to be approved. In the latter case, the surfaces on which the fillet weld beads are to be deposited are to be cut back by machining and then built up to original dimensions with weld metal from the consumable to be approved.

Table 11.8.1 Requirements for deposited metal tests (manual, semi-automatic and automatic multi-run techniques)

Grade	0,2% proof stress N/mm^2 minimum	1% proof stress N/mm^2 minimum	Tensile strength N/mm^2 minimum	Elongation on 50 mm % minimum	Charpy V-notch impact tests		
					Chemical test temperature °C	Cryogenic test temperature °C	Average energy *See* Note 1 J minimum
304L	270	310	500	25	–20	–196	29
304LN	305	345	530	22	–20	–196	29
316L	270	310	500	22	–20	–196	29
316LN	305	345	530	22	–20	–196	29
317L	305	345	530	22	–20	–196	29
317LN	340	380	570	22	–20	–196	29
321	290	330	550	22	–20	–196	29
347	290	330	550	22	–20	–196	29
S 31254	370	410	650	22	–20	–196	29
N 08904	270	310	500	22	–20	–196	29
SS/CMn	270	310	500	22	–20	–60	29
S 31260	485	525	690	20	–20	*see* Note 2	40
S 31803	450	490	620	25	–20		40
S 32550	550	590	760	15	–20		40
S 32750	550	590	800	15	–20		40
S 32760	550	590	750	25	–20		40
Dup/CMn	270	310	500	22	–20	*see* Note 2	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. Approval for cryogenic applications is to be obtained at the procedure approval stage.

Table 11.8.2 Requirements for butt weld tests (all techniques)

Grade	Tensile strength N/mm^2 minimum	Bend test ratio: $\frac{D}{t}$	Weld ferrite content %	Charpy V-notch impact tests		
				Chemical test temperature °C	Cryogenic test temperature °C	Average energy (*see* Note 1) J minimum
304L	500	3	4–12	–20	–196	27
304LN	530	3	4–12	–20	–196	27
316L	500	3	4–12	–20	–196	27
316LN	530	3	4–12	–20	–196	27
317L	530	3	4–12	–20	–196	27
317LN	570	3	4–12	–20	–196	27
321	550	3	4–12	–20	–196	27
347	550	3	4–12	–20	–196	27
S 31254	650	3	(*see* Note 2)	–20	–196	27
N 08904	500	3	(*see* Note 2)	–20	–196	27
SS/CMn	500	3	4–12	–20	–60	27
S 31260	690	4	35–65	–20	(*see* Note 3)	40
S 31803	620	3	35–65	–20		40
S 32550	760	6	35–65	–20		40
S 32750	800	6	35–65	–20		40
S 32760	750	6	35–65	–20		40
Dup/CMn	500	3	(*see* Note 2)	–20	(*see* Note 3)	40

NOTES
1. Energy values from individual impact test specimens are to comply with 1.4.3.
2. To be reported for special consideration.
3. Approval for cryogenic applications is to be obtained at the procedure approval stage.

8.4.2 The ferrite content at the centre of the weld metal in each fillet weld bead of each assembly is to be determined from the centre macro-section by physical or metallographic means, and reported. The method of determination is also to be reported to LR.

8.4.3 Where approval is sought for fillet welding only, corrosion testing is to be carried out in accordance with 8.3.4 from a sample taken from the deposited metal test assembly.

8.5 Annual tests

8.5.1 Annual tests are to be carried out as required by the relevant Section appropriate to the type of consumable and welding technique. The tests are to include a weld ferrite content in accordance with 8.2.4 or 8.3.3 as appropriate.

8.5.2 The results of all tests are to comply with the requirements given in Table 11.8.1 and Table 11.8.2 as appropriate.

■ *Section 9* Consumables for welding aluminium alloys

9.1 General

9.1.1 Tests for the approval of consumables intended for welding the aluminium alloys detailed in Chapter 8 are to be carried out generally in accordance with the requirements of Sections 1, 2 and 5, except as otherwise detailed in this Section.

9.1.2 Approval will be indicated by the grade shown in Table 11.9.1. Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies, and may be of any temper listed in LR Rules.

9.1.3 The welding technique will be indicated in the approval grading by a letter:

- m – manual multi-run welding (GTAW),
- S – semi-automatic multi-run welding (GMAW),
- M – automatic multi-run welding (GTAW or GMAW),
- T – automatic two-run welding (GMAW).

9.1.4 The compositions of the shielding gas and the filler/electrode wire are to be reported.

9.1.5 Approval granted using the multi-run technique for a specific filler/electrode wire with a gas in one of the groups listed in Table 11.9.2 will extend to any other gas compositions within that same group, provided that the gas composition is within the range recommended by the consumable manufacturer, subject to agreement with LR.

9.1.6 Approval granted for the two-run technique will be for a specific shielding gas composition; additional tests may be required if a change in shielding gas composition is sought.

Table 11.9.1 Requirements for butt weld tests

Consumable Approval Grade (*see* Note 1)	Base material used for the test	Tensile strength N/mm^2 minimum	Bend test ratio $\frac{D}{t}$
LR RA/LR WA	5754	190	3
LR RB/LR WB	5086	240	6
LR RC1/LR WC1	5083	275	6
LR RC2/LR WC2 (*see* Note 2)	5383 or 5456	290	6
LR RC3/LR WC3 (*see* Note 2)	5059	330	6
LR RD/LR WD (*see* Note 4)	6005A 6061 6082	170 170 170	6 6 6

NOTES
1. The prefixes ‘R’ and ‘W’ indicate ‘rod’ form (for Gas Tungsten Arc Welding (GTAW)) or ‘wire’ form (for Gas Metal Arc Welding (GMAW) and GTAW).
2. Approval of grade LR RC2/LR WC2 confers approval of 5383, 5456 and 5083 base material grade.
3. Approval of grade LR RC3/LR WC3 confers approval of 5059, 5383, 5456 and 5083 base material grades.
4. Approval of grade LR RD/LR WD confers approval of 6005A, 6061 and 6082 base material grades.

Table 11.9.2 Shielding gas compositions

Group	Gas composition (Vol. %) (*see* Note)	
	Helium	Argon
I-1	–	100
I-2	100	–
I-3	>0 ≤33	Remainder
I-4	>33 ≤66	Remainder
I-5	>66 ≤95	Remainder
S	Special gas	

NOTE
Gases of other composition (mixed gases) or special purity may be considered as special gases and will require separate approval tests.

9.1.7 On completion of welding, assemblies are to be allowed to cool naturally to ambient temperature. Welded test assemblies and test specimens are not to be subjected to any heat treatment after welding except for the alloy Grades 6005A, 6061 and 6082. These are to be allowed to naturally age at ambient temperature for a period of 72 hours from the completion of welding, before testing is carried out. A second solution heat treatment is not permitted.

9.1.8 All butt test assemblies are to be subjected to both radiographic and visual examination and imperfections such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks assessed in accordance with Intermediate Level C of ISO 10042, aided where necessary by dye penetrant and ultrasonic examination.

9.1.9 Fillet weld test assemblies and macro-sections are to be visually examined for imperfections, such as lack of fusion, lack of penetration, cavities, inclusions, pores and cracks, in accordance with Intermediate Level C of ISO 10042, aided where necessary by radiographic and dye penetrant examination.

9.2 Approval tests for manual, semi-automatic and automatic multi-run techniques

9.2.1 Plate of the corresponding type of aluminium alloy and of appropriate thickness is to be used for the preparation of the weld test assemblies.

9.2.2 The welding parameters are to be within the range recommended by the manufacturer and are to be reported.

9.2.3 Welded assemblies are to be prepared and tested in accordance with 9.3, 9.4 and 9.5.

9.3 Deposited metal test assembly

9.3.1 One assembly is to be prepared in the downhand position as shown in Fig. 11.9.1.

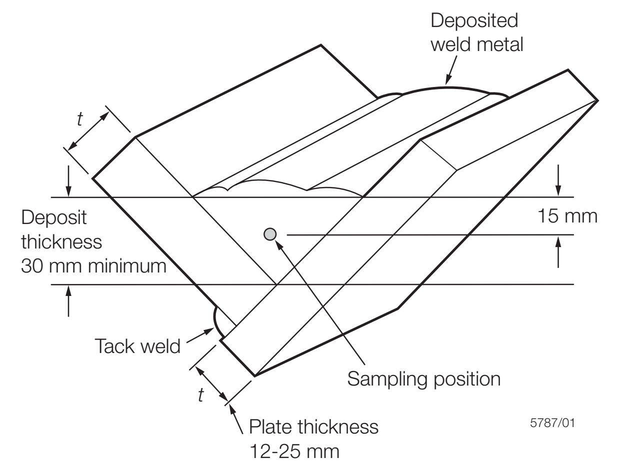


Fig. 11.9.1 Deposited metal test assembly

9.3.2 The chemical composition of the plate used for the assembly is to be compatible with the weld metal.

9.3.3 The thickness of the plate used, and the length of the assembly, are to be appropriate to the welding process. The plate thickness is to be not less than 12 mm.

9.3.4 For the approval of filler wire/gas and electrode wire/gas combinations for manual or semi-automatic welding by GTAW or GMAW, one test assembly is to be welded using any size of wire within the range for which approval is sought.

9.3.5 For automatic multi-run approval, one test assembly is to be welded by the respective process using the recommended diameter of wire.

9.3.6 The weld metal is to be deposited in multi-run layers in accordance with normal practice. The direction of deposition of each layer is to alternate from each end of the plate.

9.3.7 The deposited weld metal in the assembly is to be analysed and reported including the contents of all significant elements. The elements reported will be dependent on the type of aluminium alloy for which approval of the consumables is requested. The results of the analysis are not to exceed the limit values specified in the standards or by the manufacturer, the narrower tolerances being applicable in each case.

9.4 Butt weld test assemblies

9.4.1 Plate of the corresponding type of aluminium alloy and of an appropriate thickness is to be used for the preparation of the test assemblies.

9.4.2 In order to ensure sound and representative welds, it is essential that test assemblies are cleaned and degreased prior to welding. Assemblies as shown in Fig. 11.9.2 are to be prepared for each welding position (downhand, horizontal-vertical, vertical-upward, vertical-downward, and overhead) for which the consumable is recommended by the manufacturer; except that consumables satisfying the requirements for downhand and vertical-upward positions will be considered as also complying with the requirements for the horizontal-vertical position. Any wire diameter(s) to be approved may be used.

9.4.3 One assembly, as shown in Fig. 11.9.3, is to be prepared for welding in the downhand position. The assembly is to be welded using, for the first run, wire of the smallest diameter recommended by the manufacturer and, for the remaining runs, wire of the largest diameter to be approved.

9.4.4 The welding conditions are to be in accordance with the recommendations of the manufacturer and are to be reported in detail.

9.4.5 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.4.6 The test specimens are to be taken from the welded assemblies as shown in Fig. 11.9.2 and Fig. 11.9.3. For each assembly they are to comprise:

- 2 transverse tensile specimens;
- 2 face bend specimens; and
- 2 root bend specimens.

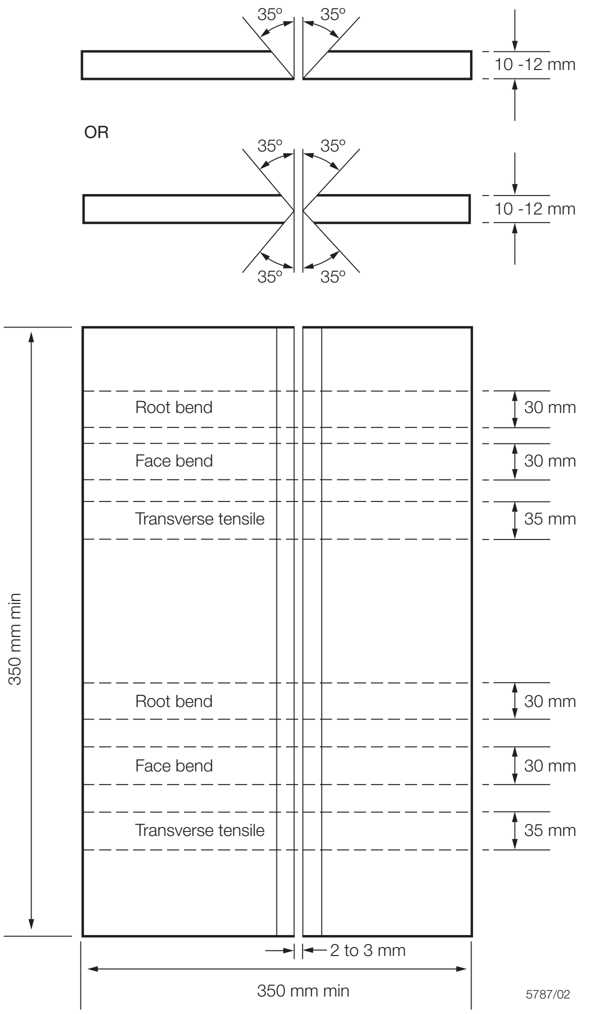


Fig. 11.9.2
Butt weld test assembly
(positional, multi-run technique)

9.4.7 All tensile test specimens are to have a tensile strength not less than the respective value shown in Table 11.9.1. The position of each fracture is to be reported.

9.4.8 The bend test specimens are to be bent around a former having a diameter not more than the number of times the thickness of the test specimen, as shown in Table 11.9.1, and can be considered as complying with the requirements if, after bending to an angle of not less than 180°, no crack or other open defect exceeding 3 mm in length can be seen on the outer surface. Flaws appearing at the corners of a test specimen may be ignored.

9.4.9 In order to obtain uniform bending of the bend test specimens, it is recommended that the wrap-around or guided bend test using a roller method is employed.

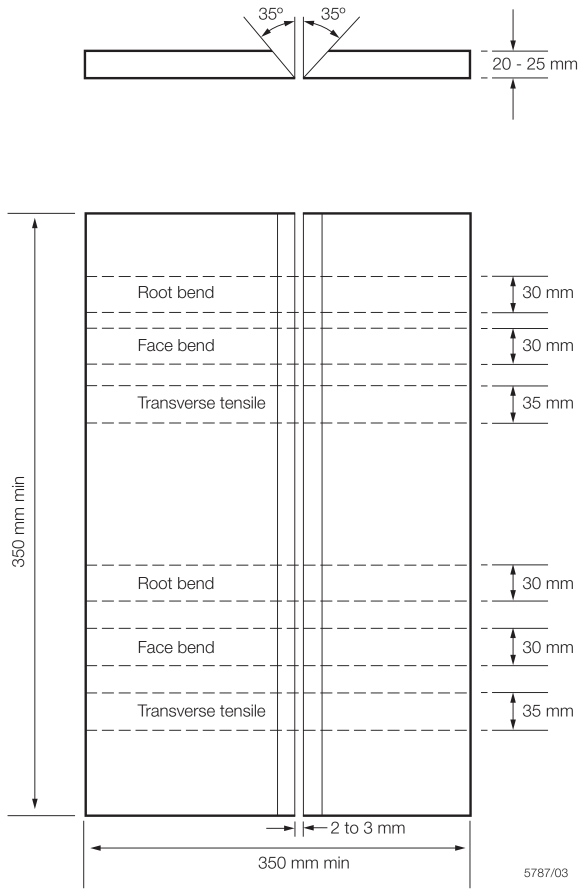


Fig. 11.9.3
Butt weld test assembly
(downhand, multi-run technique)

9.5 Fillet weld test assembly

9.5.1 When approval is being sought for both butt and fillet welding, one assembly is to be prepared and welded in the horizontal-vertical position and tested in accordance with the appropriate requirements of 3.5, except that the plates are to be of an aluminium alloy compatible with the weld metal, that no hardness tests are required and that for automatic multi-run approval only one fillet weld bead is to be made using the recommended wire diameter. In this case, the bead size is to be as large as the maximum single bead size recommended by the manufacturer for fillet welding.

9.5.2 When approval is being sought for fillet welding only, one assembly is to be prepared and welded in each position for which approval is sought, and tested as detailed in 9.5.1.

9.5.3 The results of examination of the macro-specimens and the fractured fillet welds are to be reported in accordance with 3.5.4 and 3.5.6. Imperfections are to be assessed in accordance with 9.1.9.

9.6 Approval tests for two-run technique

9.6.1 Two butt weld test assemblies are to be prepared using the following plate thicknesses:

(a) one with the maximum thickness for which approval is requested; and

(b) one with a thickness approximately one half to two thirds that of the maximum thickness.

9.7 Butt weld test assemblies (two-run technique)

9.7.1 The plates used are to be of the aluminium alloy appropriate to the approval required as shown in Table 11.9.1. The composition of the plate material is to be within the range specified for that alloy in Table 8.1.2 in Chapter 8 and is to be reported including all significant elements.

9.7.2 The wire diameter, edge preparation, welding current, arc voltage and travel speed are to be in accordance with the manufacturer's recommendations and are to be reported.

9.7.3 Each butt weld is to be made in two runs, one from each side. After completion of the first run, the assembly is to be left in still air until it has cooled to less than 50°C.

9.7.4 The welded assemblies are to be subjected to NDE. Imperfections are to be assessed in accordance with 9.1.8.

9.7.5 The test specimens as shown in Fig. 11.9.4 are to be prepared from each test assembly. The edges of the discards are to be polished and etched, and must show complete fusion and inter-run penetration of the welds. Each cut in the assembly is also to be examined to confirm that complete fusion and penetration have been achieved.

9.7.6 The results of the transverse tensile tests are to be as in 9.4.7 and of the bend tests as in 9.4.8. The position of the fracture in each transverse tensile specimen is to be reported.

9.8 Annual tests

9.8.1 Annual tests are to consist of the following:

(a) for combinations approved for the multi-run technique, one deposited metal assembly in 9.3 and one downhand butt assembly in 9.4;

(b) for combinations approved for the two-run technique, one butt weld assembly in plate material of thickness equal to one half to two thirds that of the maximum thickness approved.

9.8.2 For the automatic two-run technique, one butt weld assembly is to be prepared and tested in accordance with 9.7.

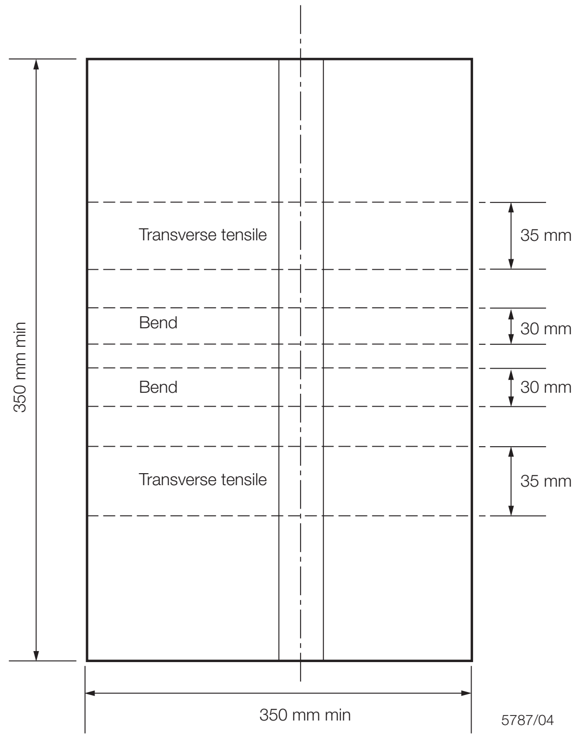


Fig. 11.9.4
Butt weld test assembly (two-run technique)

■ *Section 1* General qualification requirements

1.1 General

1.1.1 This Section applies to all welding qualifications and tests required to be performed in the course of new construction, conversions, modifications or repairs made on ships, other marine structures and their associated pressure vessels, machinery and equipment.

1.1.2 These Rules also apply to all welding work related to other applications for which Lloyd's Register (hereinafter referred to as LR) have issued Rules or have an interest.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules. All deviations are to be recorded as non-compliances and brought to the attention of the Surveyor along with the corrective actions taken. Failure to do this is considered to render the welding tests as not complying with the Rules.

1.1.4 Welding tests are to be performed under survey at the manufacturer's works. Welding procedure qualification tests and welder qualifications tests are to be performed and approved prior to commencement of fabrication or construction.

1.1.5 Weld procedure tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to and meet the technical intent of these Rules to the satisfaction of the Surveyor.

1.1.6 Welding tests that have previously been carried out may be considered for acceptance, provided that they have been supervised by an independent body acceptable to LR and the Surveyor is satisfied with the authenticity of such tests.

1.1.7 The responsibility for the performance of the weld tests rests with the manufacturer. Aspects of the welding tests, such as mechanical testing, non-destructive testing and heat treatment, may be subcontracted by the manufacturer provided that the subcontractor performs the work under the technical control and direction of the manufacturer, and this is agreed with the Surveyor prior to commencing the work.

1.1.8 In these Rules, the term 'manufacturer' is considered to include any firm or organisation that performs welding and is considered to be the shipbuilder, or construction firm, or fabricator, or material manufacturer.

1.2 Design

1.2.1 Welding procedure qualification tests are required to give assurance that construction welds made in accordance with the approved plans or the approved design have acceptable properties. It is the manufacturer's responsibility to establish and document whether a procedure is suitable for a particular application.

1.2.2 The requirements relate to mechanical properties of the weld and heat affected zone, however, other tests may be required on certain materials, for example, corrosion or fatigue tests, in order to ensure suitability for the proposed application.

1.3 Materials

1.3.1 Materials used for testing are to be of the same grade, type and from the same manufacturing process as those to be used for construction, unless prior agreement is obtained from the Surveyor. Such agreements will only apply on a case-by-case basis.

1.3.2 All materials used for testing are to be suitably marked and identifiable to the original manufacturer's material certificate.

1.4 Performance of welding tests

1.4.1 All welding and subsequent testing is to be performed in accordance with the requirements of this Chapter.

1.4.2 The manufacturer is responsible for monitoring the tests and for recording all the welding variables as specified in 2.2 and for compiling all the non-destructive examination (NDE) reports and mechanical test records for submission to the Surveyor.

1.4.3 The laboratory or testing establishment used to perform the tests is to have the necessary equipment, maintained in good order and suitably calibrated. The Surveyor is to be satisfied that the laboratory personnel have the appropriate skills and are appropriately qualified in accordance with Ch 2,1.2.1.

Section 2
Welding Procedure Qualification Tests for Steels

2.1 General

2.1.1 The requirements of this Section relate to welding procedure test requirements of carbon, carbon-manganese steels and low alloys steels. Additional requirements for austenitic and austenitic/ferritic duplex stainless steels, aluminium and copper alloys are specified in Sections 3 and 4 respectively.

2.1.2 Prior to performing the welding procedure qualification test, the manufacturer is to present to the Surveyor a preliminary Welding Procedure Specification (pWPS) detailing the welding processes, positions, joint types, materials and heat treatments to be performed during the test. The pWPS is to be presented for information prior to commencing the test.

2.1.3 The type and extent of testing to be applied to each welding procedure test is to be in accordance with subsequent Sections of this Chapter.

2.1.4 For the welding procedure approval, the welding procedure qualification tests given in this Section are to be carried out with satisfactory results. Welding procedure specifications are to refer to the test results achieved during welding procedure qualification testing.

2.2 Welding variables

2.2.1 In order that the conditions of the qualification test may be applied to production welding operations, the appropriate variables are to be recorded by the manufacturer during welding and testing from the following list:

(a) The unique qualification reference number and the date of welding;
(b) The material type, grade, product form, dimensions and identification;
(c) Welding process(es), including tack welds;
(d) Joint type, dimensions and surface condition;
(e) Welding position(s);
(f) Welding technique(s), weaving, multiple electrodes, etc;
(g) Welding consumables including fluxes, shielding gases, etc;
(h) Control of consumables, baking or drying conditions, etc;
(j) Welding parameters, current, voltages, travel speeds, etc;
(k) Number and sequence of weld runs;
(l) Backing materials including any backing gas;
(m) Preheats and interpass temperatures;
(n) Methods used for cleaning and inspection of root deposits;
(o) Post-weld heat treatment, temperature and cycle times;
(p) Special weld profiling requirements.

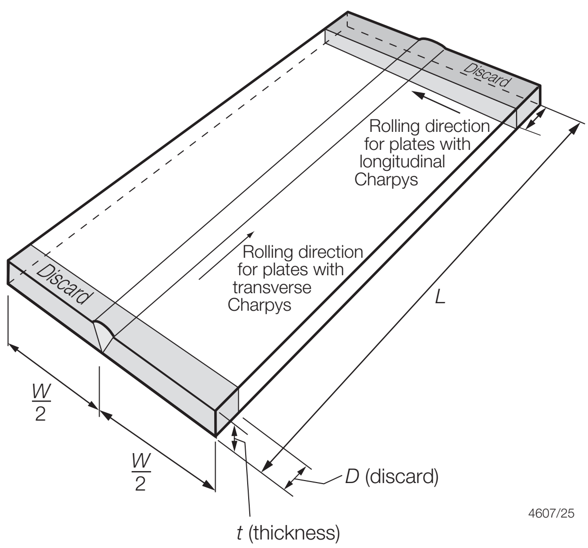
2.2.2 Other variables may need to be recorded depending on the particular welding process or application and are to be agreed with the Surveyor, for example the peak and base current and cycle times for pulse welding, electrode type and nozzle size for GTAW welding, etc.

2.3 Steel test assemblies

2.3.1 Tests are to be performed using the welding process and positions anticipated for actual construction. The weld test assemblies are to be representative of construction conditions and are to be welded in the same manner as intended for the actual production welds. Where pre-fabrication primers are used in the shipyard, these are to be included in the test assemblies.

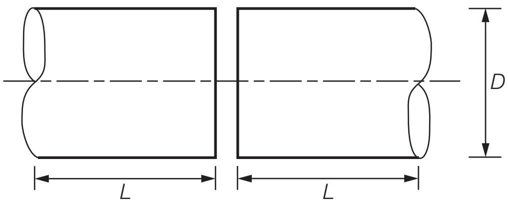
2.3.2 For plate tests, the direction of plate rolling relative to the weld direction is to be considered. Where the material used for the test requires longitudinal impact tests, the plate rolling direction is to be perpendicular to the weld direction and for material which requires impact testing in the transverse direction, the rolling direction is to be parallel to the weld direction.

2.3.3 Typical test assemblies are shown in Fig. 12.2.1(a) to (c). These are a minimum requirement to permit the removal of all the necessary mechanical test specimens. Where impact tests or other toughness tests are required, the total width is not to be less than 8 times the material thickness of the thicker material being joined.



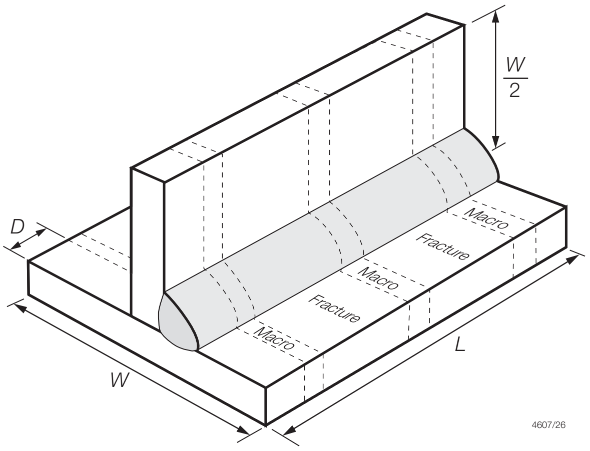
Welding Processes	L (min) mm	W (min) mm	D (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	400	75

Fig. 12.2.1(a) Butt weld test assembly in plate



L = 150 mm minimum
D = Outside diameter

Fig. 12.2.1(b) Butt weld test assembly in pipe



Welding Processes	*L* (min) mm	*W* (min) mm	*D* (min) mm
Manual/Semi-automatic	350	300	50
Automatic	1000	300	75

Fig. 12.2.1(c) Fillet weld test assembly in plate

2.3.4 Welding procedure test assemblies are to be welded separately from production welds and are to be marked with the unique test identification number. The individual pieces of the test assembly may be held together to maintain their relative joint conditions by means of suitable tack welds, clamps or strongbacks.

2.3.5 Welding of the test assemblies and testing of test specimens is to be monitored by the Surveyor.

2.3.6 The test assembly is to be placed in one of the welding positions shown in Fig. 12.2.2(a) to (d), as specified in the test Welding Procedure Specification (pWPS) and the specified level of preheat applied prior to the start of welding.

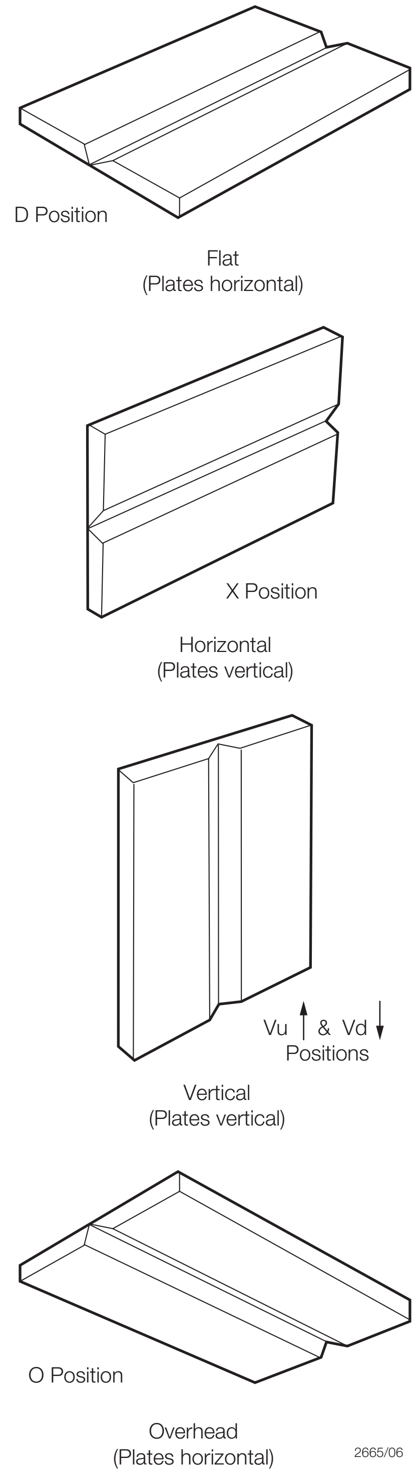
2.3.7 Designations for equivalent welding positions shown by different standards are shown in Table 12.2.1.

Table 12.2.1 Equivalent designations of welding positions

Weld position		Standard	
		ISO 6947	AWS
Plate butt welds			
Flat	D	PA	1G
Horizontal	X	PC	2G
Vertical, weld up	Vu	PF	3G
Vertical, weld down	Vd	PG	3G
Overhead	O	PE	4G
Pipe butt welds			
Pipe horizontal, rotated, weld horizontal	D	PA	1G
Pipe vertical, not rotated, weld horizontal	X	PC	2G
Pipe horizontal, not rotated, weld flat, vertical and overhead	D+Vu+O D+Vd+O	PF PG	5G
Pipe inclination fixed, not rotated	45°	H-L045 J-L045	6G
Plate fillet welds			
Flat	D	PA	1F
Horizontal	X	PB	2F
Vertical up	Vu	PF	3F
Vertical down	Vd	PG	3F
Overhead	O	PD	4F
Pipe fillet welds			
Flat, pipe rotated	D	PA	1FR
Horizontal, pipe fixed	X	PB	2F
Horizontal, pipe rotated	D	PB	2FR
Overhead, pipe fixed	O	PD	4F
Multiple, pipe fixed	D+Vu+O D+Vd+O	PF PG	5F

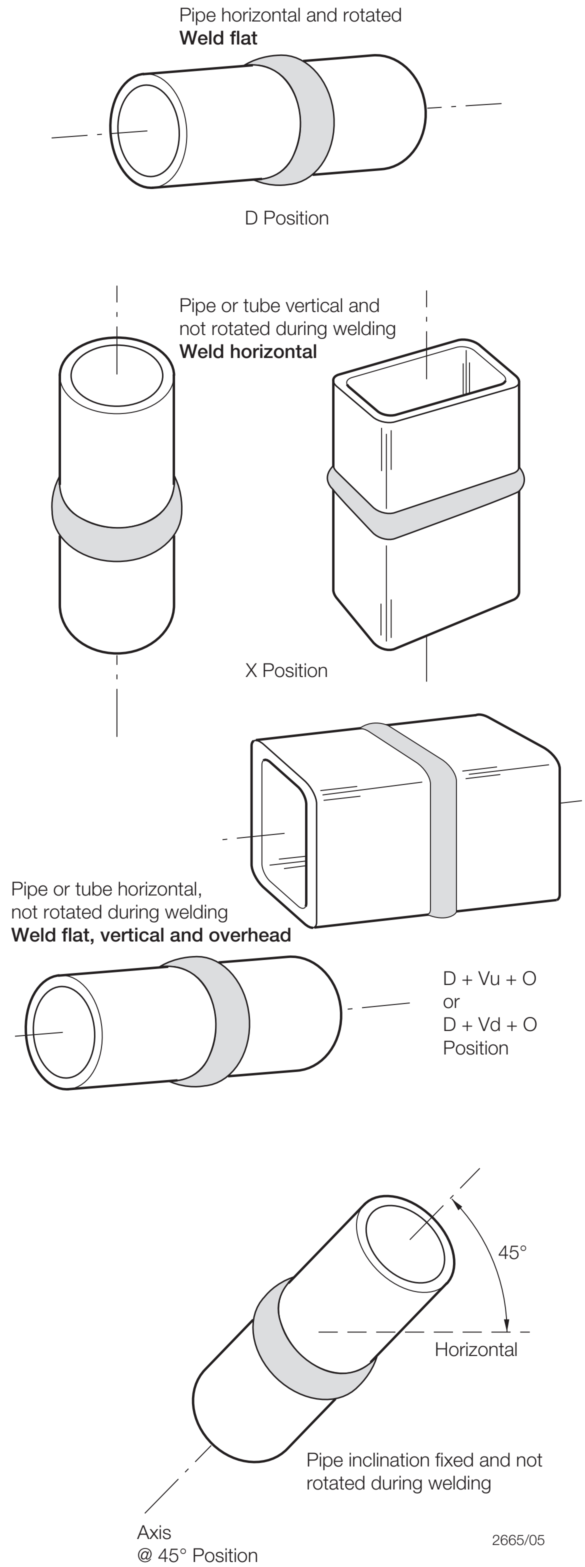
2.4 Welding of steel test assemblies

2.4.1 Welding of the test assembly is to be carried out in accordance with the agreed pWPS. Where, during the progress of the test, it is found necessary to change the conditions specified on the pWPS, this is to be brought to the attention of the Surveyor. If agreed, the test may be permitted to continue with the new conditions and these are to be recorded.



Position of test plates for plate assemblies

Fig. 12.2.2(a) Plate butt weld test positions



Position of pipes and welds for qualification weld test assemblies

Fig. 12.2.2(b) Pipe butt weld test positions

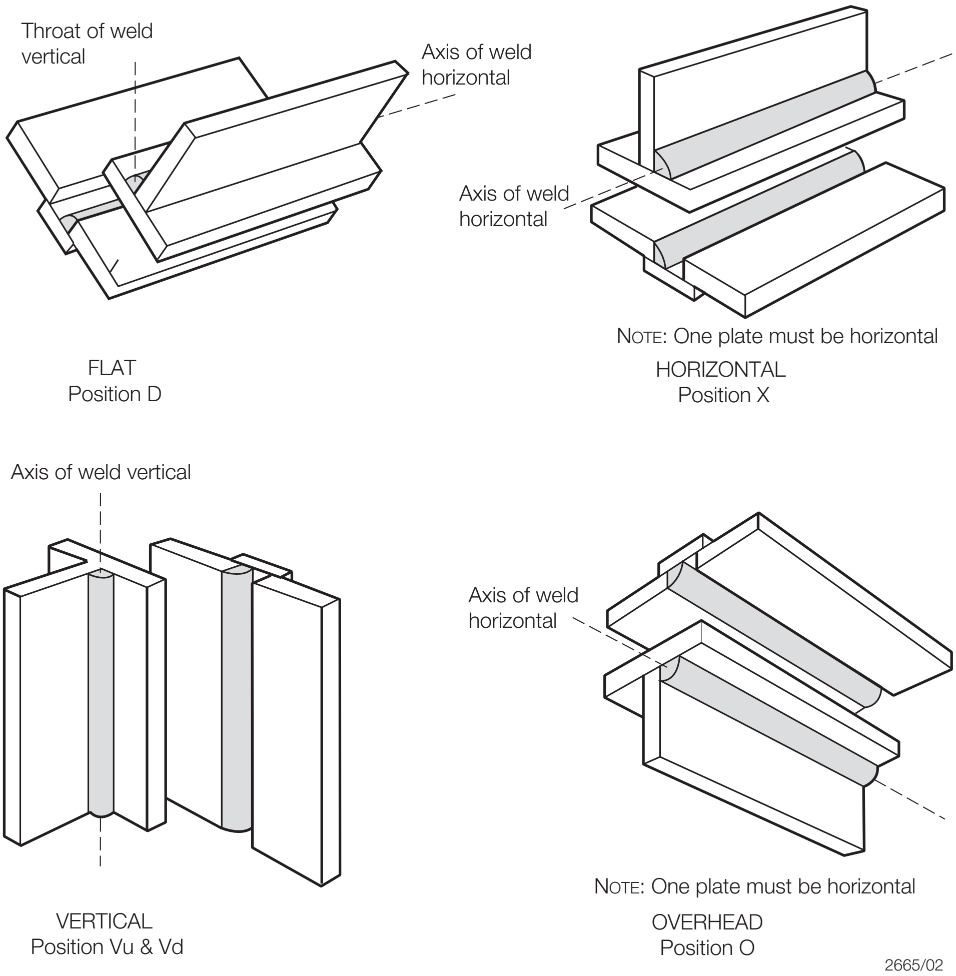


Fig. 12.2.2(c) Plate fillet weld test positions

2.4.2 Where the production work requires welding over tack welds, the test is to simulate this condition and the tack welds are to be included in the inspection length of the test weld and their position recorded.

2.4.3 For manual and semi-automatic welding processes, weld stops and re-starts are to be included in the inspection length of the test weld.

2.4.4 Fillet weld test assemblies are welded on one side only.

2.4.5 Where the construction welding is predominately fillet welding, in addition to the butt weld qualification test, a fillet weld qualification test is to be performed to confirm that acceptable weld quality is achieved.

2.5 Non-destructive examination (NDE)

2.5.1 On completion of welding, prior to sectioning for mechanical tests, the inspection length of the test assembly is to be subjected to both visual examination and surface crack detection.

2.5.2 Butt weld assemblies are also to be subjected to radiographic or ultrasonic examination over the whole inspection length of the weld.

2.5.3 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

2.5.4 Where post-weld heat treatment is required, NDE is to be performed after the heat treatment is complete.

2.5.5 All NDEs are to be carried out in accordance with the requirements of Ch 1,5. Assessment of results is to be in accordance with ISO 5817 Level B except for excess convexity and excess throat thickness where Level C will apply. Linear porosity is not permitted.

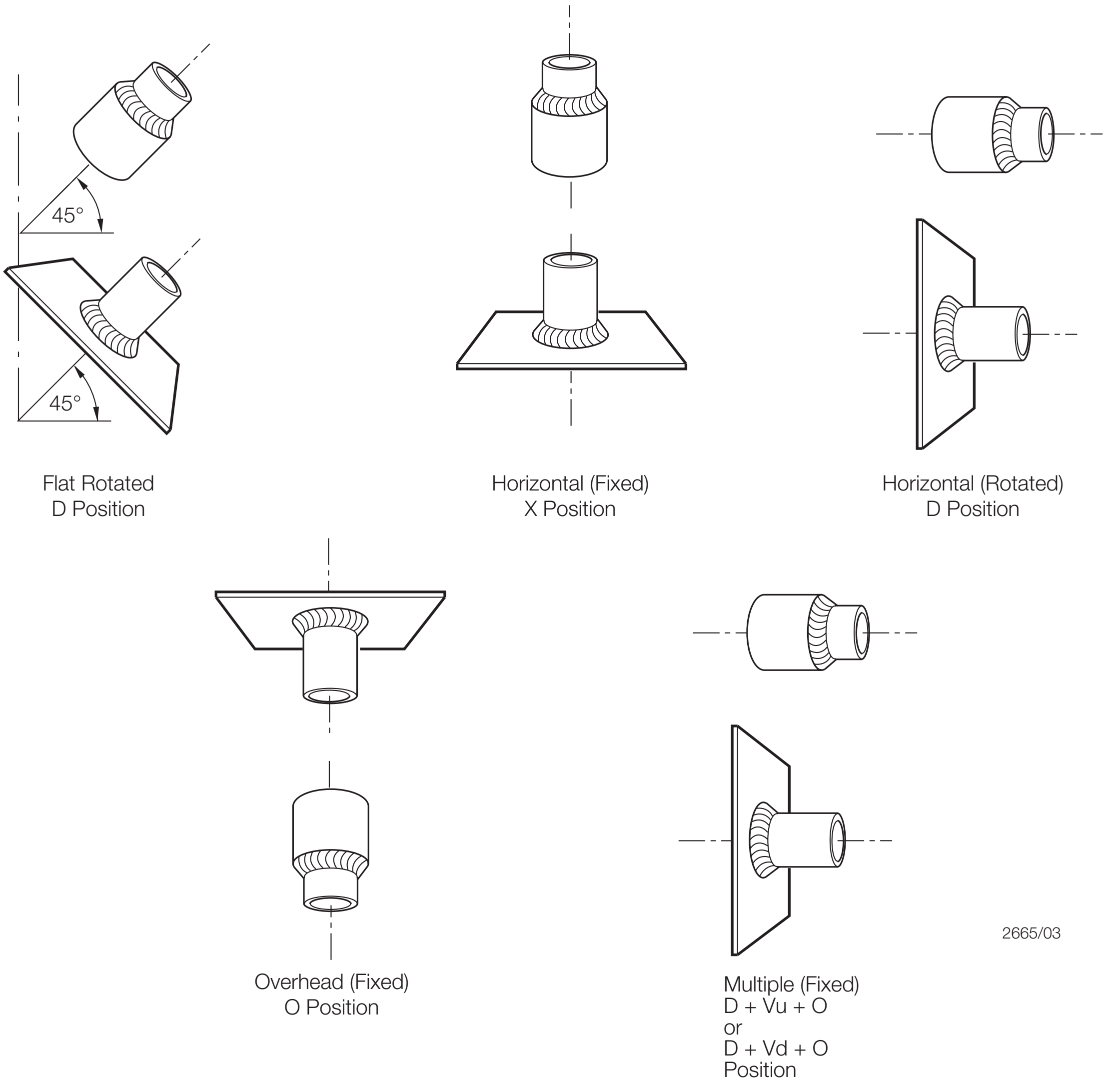


Fig. 12.2.2(d) Pipe fillet weld test positions

2.5.6 As an alternative to radiography, ultrasonic examination may be carried out and acceptance criteria that are considered to result in equivalent weld quality (in accordance with 2.5.5) are to be agreed, with the Surveyor, prior to the tests being carried out. Ultrasonic testing will be subject to the thickness limitation specified in Ch 13,2.12.5.

2.5.7 Where the test assembly does not satisfy the non-destructive examination acceptance criteria, the test is to be rejected. A duplicate test assembly may be welded using the original welding conditions. If this fails NDE, the welding procedure is to be considered as incapable of achieving the requirements without modification.

2.5.8 Subject to prior agreement with the Surveyor, where unacceptable imperfections are of a volumetric nature and are localised in one small area of the test assembly, the test may be permitted to continue and specimens for destructive testing may be removed, avoiding this area.

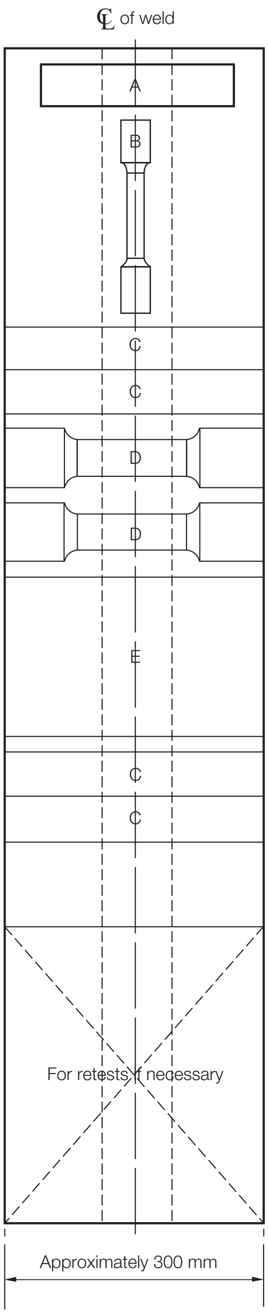
2.6 Destructive tests – General requirements

2.6.1 The weld test assembly may only be sectioned for destructive testing after any heat treatment and the required non-destructive examinations have been completed successfully.

2.6.2 The dimensions of the test specimens and testing conditions are to be in accordance with the requirements specified in Chapter 2.

2.6.3 The results of destructive tests are to be assessed in accordance with the acceptance criteria specified in 2.12, unless other, more stringent requirements are specified for the application.

2.6.4 Where a weld test is made between materials of different grades, the acceptance criteria that are to be applied are those applicable to the lower grade material.



Test requirements
A One macro including hardness survey
B All weld metal tensile test
C Four bend tests.
Two root bends and two face bends for thickness up to 12 mm.
For thickness above 12 mm four side bends
D Two transverse tensiles
E Five sets of Charpy V-notch impact tests, notched at the following positions:
1 set at weld centre
1 set at fusion line (FL)
1 set at FL + 2 mm
1 set at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
1 set at FL + 10 mm (if required)

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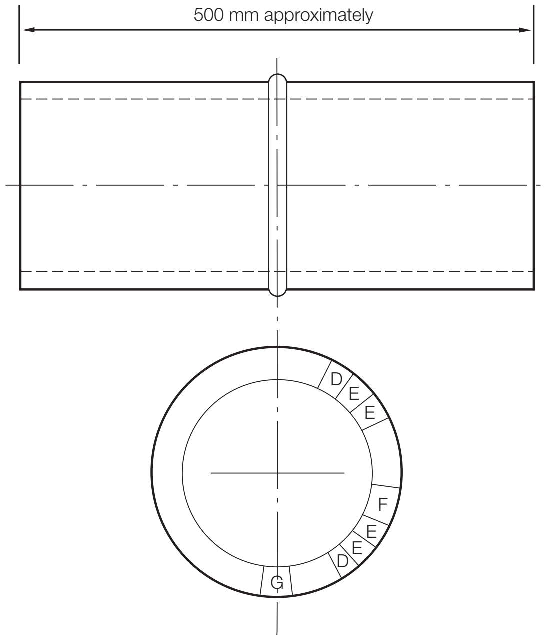
Fig. 12.2.3
Butt welds in plate and pipe over 750 mm diameter



The diameter of the test piece is to be a minimum of *D*/2
where
D is the maximum diameter of the pipe to be welded in construction

Test requirements
A Visual examination
B Surface crack detection
C 100% radiographic examination
D Two transverse tensile tests
E Four bend tests.
Four side bends for thickness greater than 12 mm.
In other cases, two face and two root bends
F Four sets Charpy V-notch impact tests
1 set notched at centre of weld
1 set notched at fusion line (FL)
1 set notched at FL + 2 mm
1 set notched at FL + 5 mm (if required by Figs. 12.2.6 and 12.2.7)
G One macro specimen including hardness survey

Fig. 12.2.4
Butt welds in pipe less than 750 mm diameter

2.7 Destructive tests for steel butt welds

2.7.1 The test assembly is to be sectioned for mechanical testing in accordance with Figs. 12.2.3 or 12.2.4.

2.7.2 The longitudinal all weld metal tensile test specimen is to be of circular cross-section as detailed in Ch 11,2.1.1. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from each respective area of the weld. This does not apply to the process or consumables used to make the root or first weld run. During the test, the yield or proof stress, ultimate tensile strength, and elongation to failure are to be recorded.

2.7.3 Where approved welding consumables have been used, the longitudinal all weld metal tensile test may be omitted.

2.7.4 The transverse tensile test specimen is to be of full thickness with the dimensions shown in Ch 11,2.1.1. The tensile strength and fracture locations are to be reported.

2.7.5 Where the maximum load required to fracture the transverse tensile specimen is likely to exceed the capacity of the tensile testing equipment, several tensile specimens may be removed through the thickness and tested. Specimens are to be prepared such that they overlap in the thickness direction so that the full plate thickness is tested.

2.7.6 Transverse bend specimens of rectangular section are to be prepared with the weld centred in the middle of the specimen as shown in Fig. 12.2.5. For material of thickness 12 mm or greater, the face and root bends may be substituted by side bend tests. The weld reinforcement may be removed by grinding or machining prior to testing and the edges rounded to a radius not exceeding 10 per cent of the specimen thickness. Each specimen is to be bent through an angle of at least 180°. The bend test ratio is to be the lesser of the following:

(a) D_f = $(D/t) + 1$

or

(b) D_f = $100/E_m$ (rounded up to the next whole number)

where

D_f = is the bend test ratio

(D/t) = is the value from Tables 11.3.3, 11.4.3 or 11.8.2 in Chapter 11, as appropriate

E_m = is the minimum specified percentage elongation for the test material (based on a proportional gauge length of $5{,}65\sqrt{S_o}$)

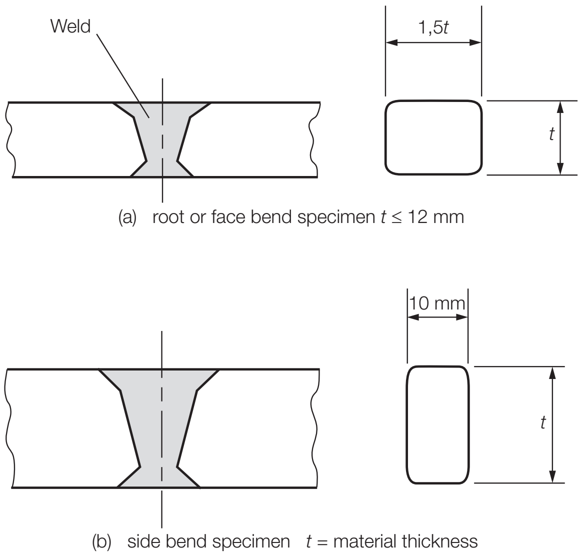


Fig. 12.2.5 Transverse bend test specimens

2.7.7 Where the weld test is made between different material types, the requirements of 2.7.8 are to be applied to the material with the lower toughness specification.

2.7.8 For hull structural steels, impact test specimens are to be prepared from the locations shown in Figs. 12.2.6 or 12.2.7, with the notch perpendicular to the plate surface and have the dimensions and proportions in accordance with Ch 2,3. Where more than one welding process or type of consumable has been used to make the weld, test specimens are also to be removed from these respective parts of the weld. Note that this does not apply to the welding process or consumables used solely to make the root or first weld run. Where the weld thickness exceeds 50 mm, an additional set of impact tests is required from the root area of the weld irrespective or whether different welding process or welding consumables are used as shown in Figs. 12.2.6 and 12.2.7.

2.7.9 For offshore structures and pressure vessels, impact test specimens are not required to be notched at the FL + 10 mm location. Where more than one welding process or type of consumable has been used to make the weld, test specimens are to be removed from the respective areas of the weld. This does not apply to the process or consumables used solely to make the root or first weld run.

2.7.10 At least one macro examination specimen is to be removed from the test plate, near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone and be prepared and etched to clearly reveal the weld runs and the heat affected zone. Examination is to be performed under a magnification of between x5 and x10.

2.7.11 A chemical analysis of the weld metal is to be performed on the macro specimen where approved welding consumables have not been used. The results are to comply with the limits given in the welding consumable specification.

2.7.12 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.8, using a test load not in excess of 10 kg. For each row of indents, there are to be a minimum of 3 individual indentations in the weld metal, the heat affected zones (both sides) and the base metal (both sides). The recommended distance between indents is 1,0 mm, but the distance between indents should not be less than the minimum specified in ISO 6507/1.

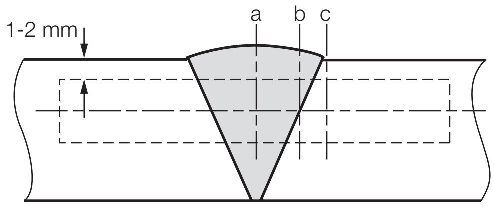
2.8 Destructive tests for steel fillet welds

2.8.1 Fillet weld test assemblies are to be sectioned for destructive testing in accordance with Fig. 12.2.1(c) and as follows:

(a) two fracture tests;
(b) three macro-sections;
(c) one hardness survey.

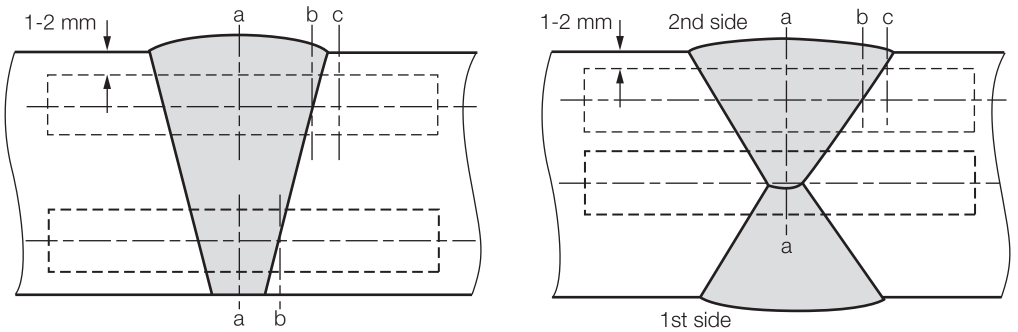
2.8.2 Two fracture test specimens are to be removed from the test weld and are to be subjected to testing by bending the upright plate onto the through plate to produce fracture, as shown in Fig. 12.2.1(c).

(a) $t \leq$ 50 mm, *see* Note



NOTE
For one side single run welding over 20 mm notch location 'a' is to be added on root side

(a) t > 50 mm



Notch locations:
a : centre of weld 'WM'
b : on fusion line 'FL'
c : in HAZ, 2mm from fusion line

Fig. 12.2.6 Locations of V-notch for butt weld of normal heat input (heat input ≤ 50 kJ/cm)

2.8.3 At least three macro examination specimens are to be removed from the test plate. The specimens are to include the complete cross-section of the weld and the heat affected zone and is to be prepared to clearly reveal the weld runs and the heat affected zone. One of the specimens is to include a weld stop/start position. Examination is to be performed under a magnification of between x5 and x10.

2.8.4 A Vickers hardness survey is to be performed on the macro specimen taken from the weld start end of the test assembly in accordance with that shown in Fig. 12.2.9, using a test load not exceeding 10 kg.

2.9 Destructive tests for T, K, Y steel nozzle welds

2.9.1 Full penetration 'T', 'K' and 'Y' joints for structural applications and nozzle welds for pressure vessels are to be sectioned for testing in accordance with Fig. 12.2.10 and tested as detailed below:

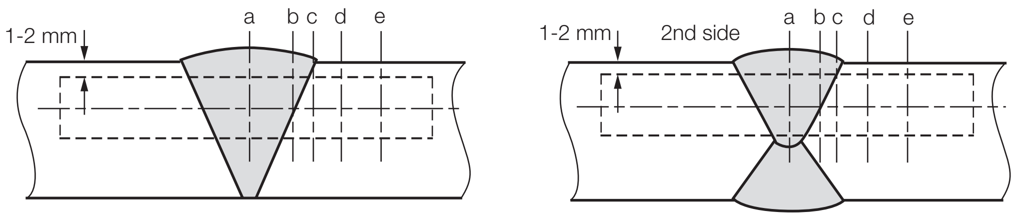
(a) three macro specimens;
(b) impact tests from the weld, fusion line and fusion line + 2 (where the material thickness permits);
(c) one hardness survey.

In addition, butt weld tests are to be performed in accordance with 2.7, using the same welding conditions, in order to verify acceptable weld and heat affected zone properties.

2.9.2 The impact tests are to be removed from the vertical (up) position 'B' in Fig. 12.2.10 and tested in accordance with 2.7.8.

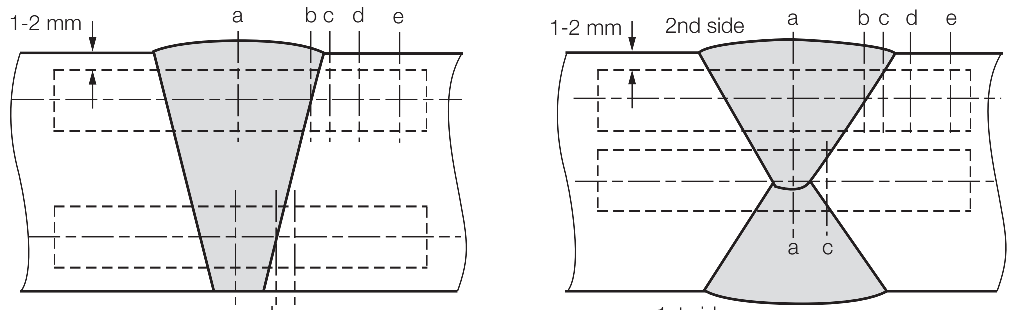
2.9.3 A Vickers hardness survey is to be performed on the macro-section removed from position 'A' or 'C' in accordance with that shown in Fig. 12.2.11 using a test load not exceeding 10 kg.

(a) $t \leq 50$ mm, *see* Note



NOTE
For one side welding with thickness over 20 mm notch location ‘a’, ‘b’ and ‘c’ are to be added on root side

(a) $t > 50$ mm



Notch locations:
a : centre of weld ‘WM’
b : on fusion line ‘FL’
c : in HAZ, 2 mm from fusion line
d : in HAZ, 5 mm from fusion line
e : in HAZ, 10 mm from fusion line in case of heat input > 200 kJ/cm

Fig. 12.2.7 Locations of V-notch for butt weld of high heat input (heat input > 50 kJ/cm)

2.10 Destructive tests for steel pipe branch welds

2.10.1 Pipe branch welds may be by either full penetration, partial penetration or fillet welded, depending on the application and the approved plans. Where these types of welded joints are used, tests are to be performed which simulate the construction conditions.

2.10.2 The test weld assembly is to simulate the smallest angle between the branch and main pipe and is to be subjected to macro-examination and hardness testing, as follows:

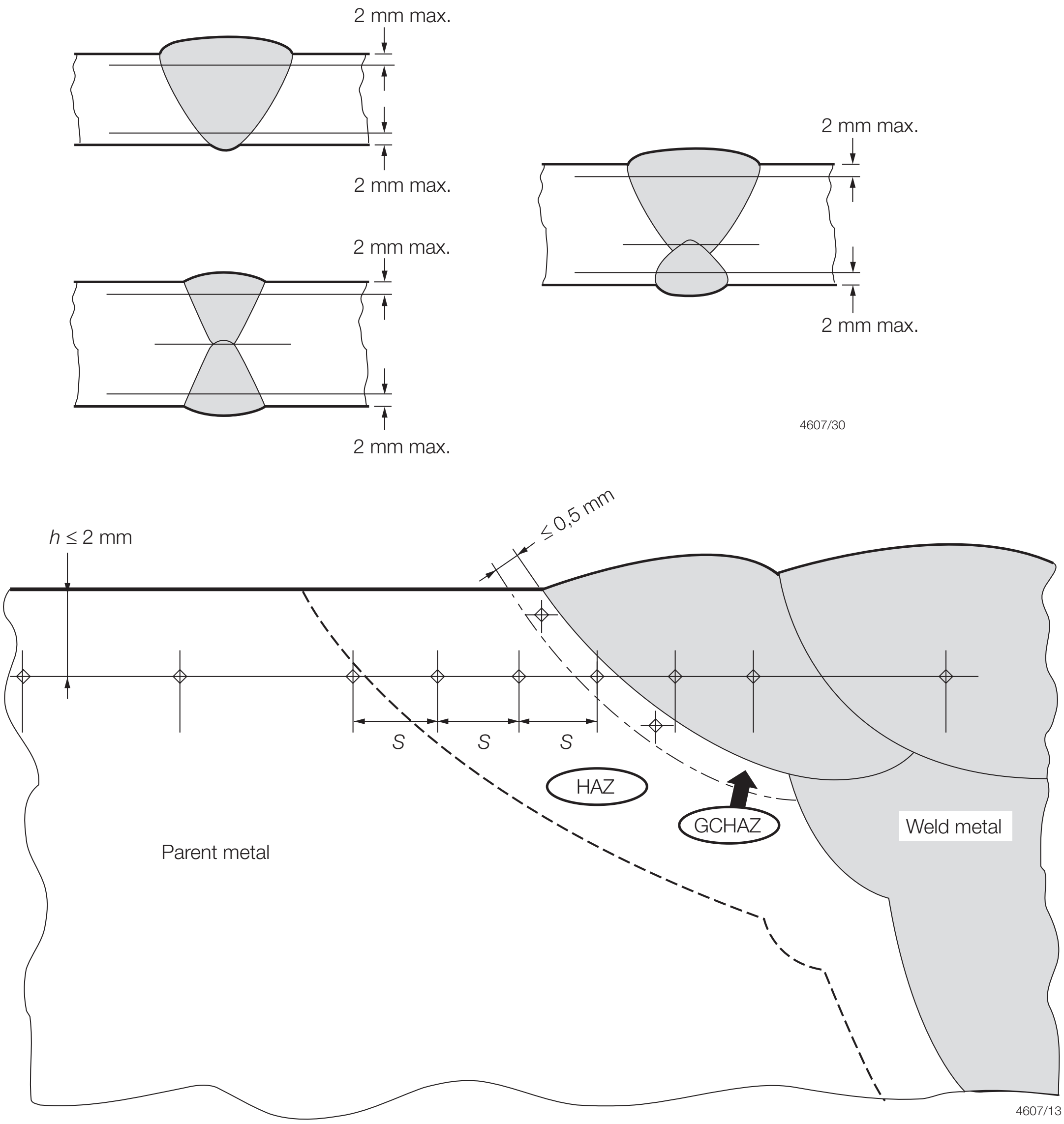
(a) For a branch weld that is full penetration, testing is to be performed in accordance with the requirements for ‘T’, ‘K’ and ‘Y’ joints in 2.9.
(b) For a branch weld that is either a partial penetration or fillet weld, testing is to be in accordance with the requirements for fillet welds in 2.8.

2.11 Destructive tests for weld cladding of steel

2.11.1 Where weld cladding or overlay is allowed by Chapter 13, and is considered as providing strength to the component to which it is welded, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that micro-sections are not required. Impact tests may be omitted where the base material does not have specified impact properties. The longitudinal tensile and bend tests are to be tested in a similar manner to transverse specimens specified in 2.7.2 and 2.7.6, respectively.

2.11.2 Where the weld cladding is not considered as contributing to the strength of the component, but is required for corrosion or wear resistance, the type and location of test specimens are to be in accordance with Fig. 12.2.12, except that tensile and impact tests are not required.

2.11.3 Where the weld cladding is applied for corrosion resistance, in addition to the above, weld metal analysis is to be performed on one of the micro-sections, on the final weld surface but 2 mm deep. The analysis is to be within the limits specified for the corrosion resistance required.



HAZ	Heat affected zone
GCHAZ	Grain coarsened heat affected zone
S	Indentation spacing

Fig. 12.2.8 Hardness testing locations for butt welds

2.12 Mechanical test acceptance criteria for steels

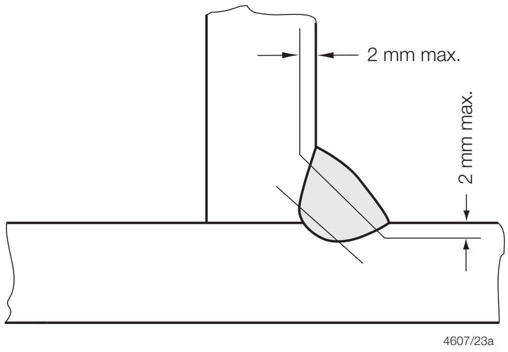
2.12.1 **Longitudinal all weld metal tensile test**:

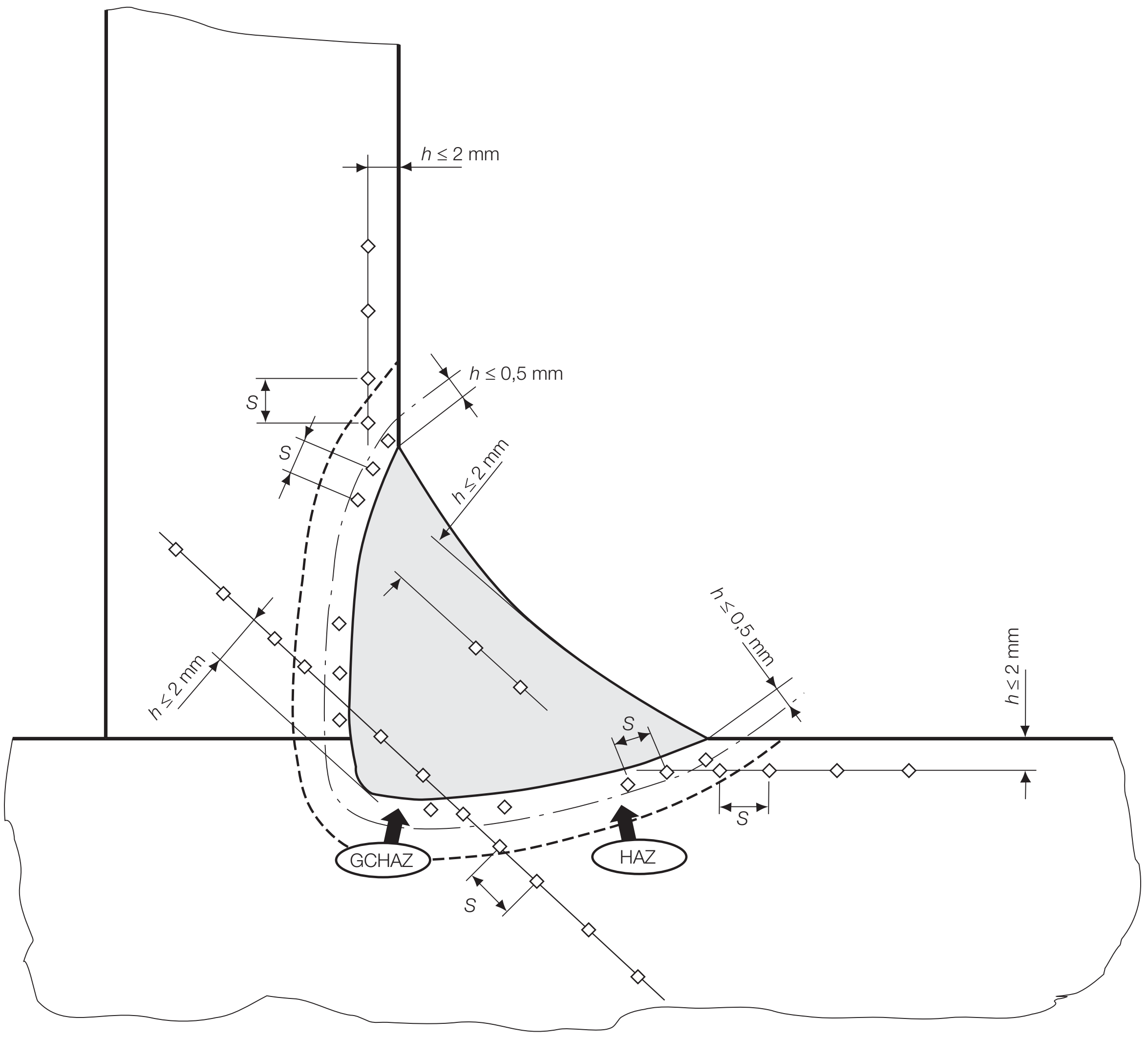
(a) In general, the longitudinal all weld tensile test is to meet the minimum properties specified in Tables 11.3.2 or 11.4.2 in Chapter 11, as appropriate to the grade of steel and welding process used in the test.

(b) Where the application is such that no consumable approvals are specified in Chapter 11, the longitudinal all weld tensile test tensile is to meet the minimum properties specified for the base materials used in the test.

(c) For pressure vessels manufactured from carbon or carbon/manganese steels, the tensile strength from the longitudinal all weld tensile test is not to be less than the minimum specified for the plate material and is not to be more than 145 N/mm^2 above this value, *see* Ch 13,4.8.3.

2.12.2 **Transverse tensile test**: The tensile strength measured from the transverse tensile test is not to be less than the minimum specified for the base material used in the test.





HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.9 Hardness test locations for fillet welds

2.12.3 **Bend tests**:

(a) In general, bend tests are to exhibit no defects exceeding 3,0 mm measured in any direction across the tension face of the specimen after being bent over the required diameter of former to the appropriate angle.

(b) Bend tests for pressure vessel applications are to exhibit no defects exceeding 3,0 mm measured along the specimen or 1,5 mm measured transverse to the specimen axis, after bending.

(c) In all cases, premature failure of the bend tests at the edges of the specimen is to not be cause for rejection unless these are associated with a weld defect.

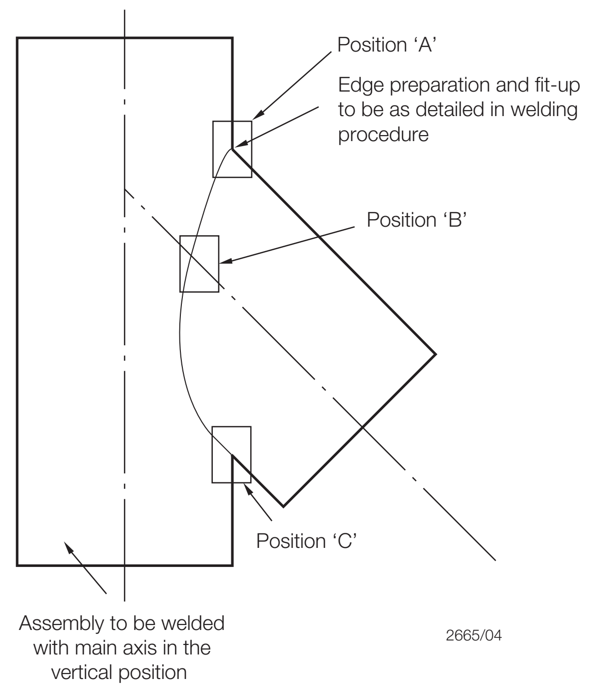


Fig. 12.2.10
Location of macro-examination test specimens for T, K and Y joints

2.12.4 **Impact toughness tests**:

(a) Impact test specimens for hull construction are to be tested at the temperature, and are to achieve the minimum impact energy, as specified in Tables 12.2.2 and 12.2.3.

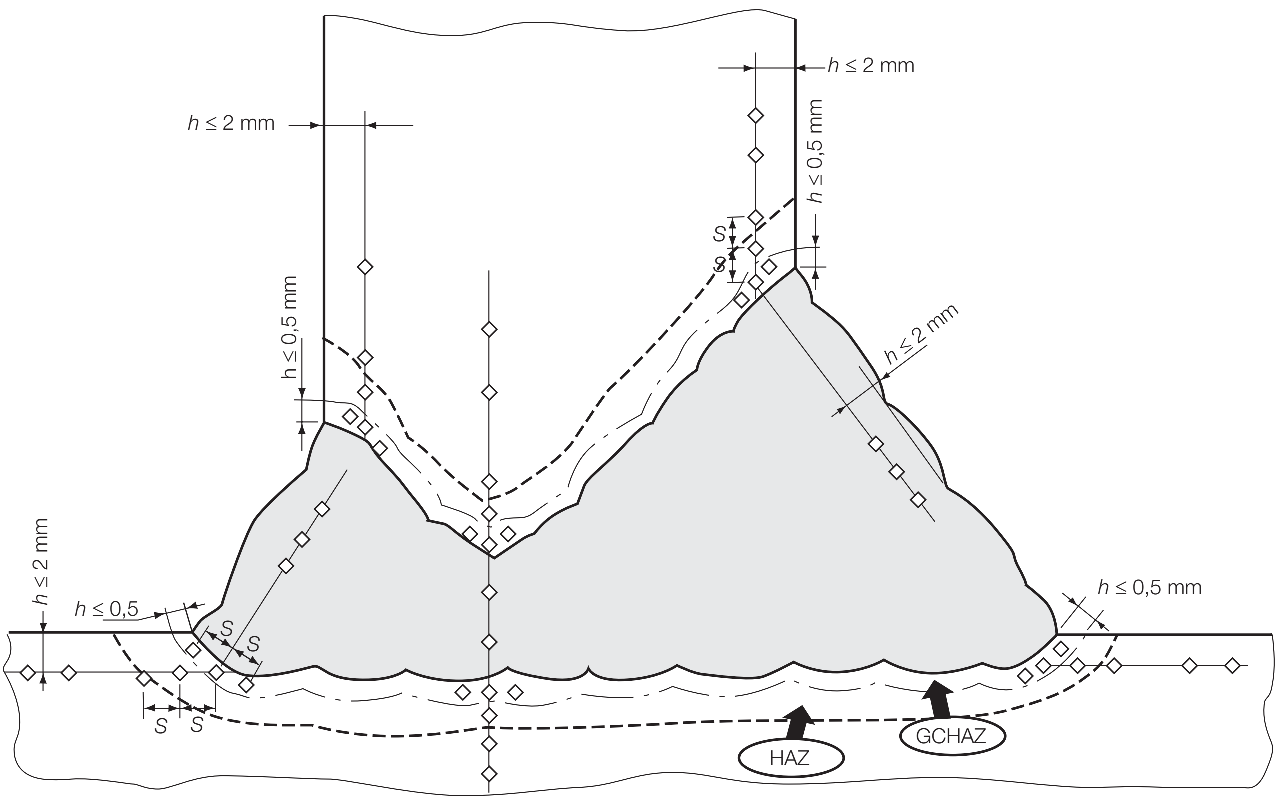
(b) Impact test specimens for applications other than hull construction are to be tested at the same temperature and achieve the same minimum energy values, as specified for the base materials used in the test.

(c) Impact test acceptance criteria are to be in accordance with the above unless the Rules applicable to the particular construction specify more stringent requirements.

(d) For quench and tempered steels, the required test temperature and absorbed energy are to be in accordance with that specified for the parent materials.

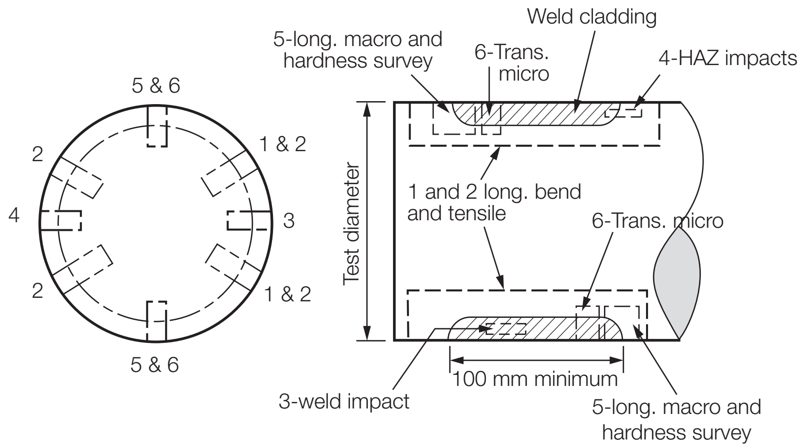
2.12.5 **Macro-examination**: The macro-section is to reveal an even weld profile blending smoothly with the base material. The weld dimensions are to be in accordance with the requirements of the pWPS and any defects present are to be assessed against the non-destructive examination acceptance criteria given in 2.5.5.

2.12.6 **Hardness surveys**: The maximum hardness value reported, is not to exceed 350 Hv for steels with a specified minimum yield strength up to ≤420 N/mm^2, nor exceed 420 Hv for steels with a specified minimum yield strength in the range 420 N/mm^2 to 690 N/mm^2.



HAZ Heat affected zone
GCHAZ Grain coarsened heat affected zone
S Indentation spacing

Fig. 12.2.11 Hardness test locations for T, K and Y joints



Test specimens
1 Longitudinal tensile test to include the weld metal, heat affected zone (HAZ) and base metal.
2 Longitudinal side bend test to include the weld metal, heat affected zone (HAZ) and base metal.
3 Weld metal Charpy V notch impact test.
4 HAZ Charpy impact test from Fusion Line and Fusion Line + 2 mm.
5 Longitudinal macro-section and hardness survey.
6 Transverse micro-section.

NOTE
In the case of shafts and pipes of circular section, the longitudinal direction is parallel to the centreline of the shaft or pipe axis.

Fig. 12.2.12 Type and location of test specimens for weld cladding

Table 12.2.2 Impact test requirements for butt joints (t ≤ 50 mm) *see* Notes 1 and 2

Grade of steel	Test temperature (°C) *see* Note 4	Value of minimum energy absorbed (J), *see* Note 4		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A, *see* Note 3 B, *see* Note 3, D E A32, A36 D32, D36 E32, E36 F32, F36	20 0 –20 20 0 –20 –40	47	34	34
A40 D40 E40 F40	20 0 –20 –40		39	39

NOTES
1. Steel with yield strength greater than 390 N/mm^2 is not permitted in thickness less than 50 mm, *see* Table 3.3.1 in Chapter 3.
2. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
3. For grade A and B steels average absorbed energy on fusion line and in heat affected zone is to be a minimum of 27 J.
4. For Naval ships both the test temperature and value of minimum energy absorbed are to be those specified for the parent material.

2.12.7 **Weld fracture or break tests (for pressure vessel test welds)**: The faces of the broken fillet weld fracture or weld break test are to be examined for defects and assessed in accordance with the non-destructive acceptance criteria given in ISO 5817 Level B, except for excess convexity and excess throat thickness where Level C will apply.

2.13 Failure to meet requirements (Retests)

2.13.1 Where a tensile, bend or hardness specimen fails to meet requirements, further test specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.1.

Table 12.2.3 Impact test requirements for butt joints (*t* > 50 mm), *see* Note 1

Grade of steel	Test temperature (ºC) see Note 2	Value of absorbed energy (J, min), *see* Note 2		
		Manual or semi-automatic welded joints		Automatically welded joints
		Downhand, Horizontal, Overhead	Vertical upward, Vertical downward	
A B D E	20 0 0 –20	34 34 47 47	34 34 38 38	34 34 38 38
AH32, AH36 DH32, DH36 EH32, EH36 FH32, FH36	20 0 –20 –40	47 47 47 47	41 41 41 41	41 41 41 41
AH40 DH40 EH40 FH40	20 0 –20 –40	50 50 50 50	46 46 46 46	46 46 46 46
AH47 DH47 EH47 FH47	20 0 –20 –40	53 53 53 53	53 53 53 53	53 53 53 53

NOTES
1. These requirements are to apply to test piece of which butt weld is perpendicular to the rolling direction of the plates.
2. For the Naval ships both the test temperature and value of minimum absorbed energy are to be those specified for the parent material.

2.13.2 Where an impact specimen fails to meet requirements, a further set of three specimens may be removed and tested in accordance with the requirements of Ch 2,1.4.4.

2.13.3 Where a macro specimen reveals a defect that is planar in nature, the welding procedure test is to be considered as not satisfying the requirements and a new test assembly is required.

2.13.4 Where a macro specimen does not meet requirements as a result of a volumetric imperfection exceeding the permitted size, two additional specimens may be removed from the same test weld and examined. If either of these macro-sections also fails to satisfy the requirements, the welding procedure is to be considered as not having met the requirements.

2.13.5 If there is a single hardness value above the maximum values specified, additional hardness tests are to be carried out, either on the reverse of the specimen, or after sufficient grinding of the tested surface. None of the additional hardness values is to exceed the maximum hardness values specified, otherwise the welding procedure is to be considered as not having met the requirements.

2.13.6 Where there is insufficient material available in the welded test assembly to provide re-test specimens, subject to prior agreement with the Surveyor, a second assembly may be welded using the same conditions as the original test weld.

2.14 Test records

2.14.1 The procedure qualification record (PQR) is to be prepared by the manufacturer and is to include details of the welding conditions used in the test specified in 2.2 and the results of all the non-destructive examinations and destructive tests, including re-tests.

2.14.2 Provided that the PQR lists all the relevant variables and there are no inconsistent features and the results satisfy the requirements, the PQR may be endorsed by the Surveyor as satisfying the requirement of the Rules, *see also* 1.1.4.

2.15 Range of approval

2.15.1 A welding procedure qualification test that has successfully met the requirements may be used for a wider range of applications than those used during the test.

2.15.2 Changes outside of the ranges specified are to require a new welding procedure test.

2.15.3 Other ranges of approval from those specified in this Section may be agreed with the Surveyor, provided that they are in accordance with recognised National or International Standards.

2.15.4 **Manufacturer**. A welding procedure qualified by a manufacturer is valid for welding in workshops under the same technical and quality management.

2.15.5 **Welding process and technique**. The welding process and welding techniques approved are to be those employed during the welding procedure qualification test. Where multiple welding processes are used, these are to be employed in the same order as that used in the welding procedure qualification test. However, it may be acceptable to delete or add a welding process where it has been used solely to make the first weld run in the root of the joint, provided back gouging or grinding of the root weld is specified on the WPS. For multi-process procedures, the welding procedure approval may be carried out with separate welding procedure tests for each welding process.

2.15.6 **Welding positions**. Approval for a test made in any position is restricted to that position. To qualify a range of positions, test assemblies are to be welded for the highest heat input position, and the lowest heat input position, and all applicable tests are to be made on those assemblies. The above excludes welding in the vertical position with travel in the downward direction which will always require separate qualification testing and only be acceptable for that position.

2.15.7 **Joint types**. A qualification test performed on a butt weld may be considered acceptable for fillet and partial penetration welds, provided the same welding conditions are used. The range of approval depending on the type of joint for butt welds is given in Table 12.2.4.

Table 12.2.4 Range of approval for different types of butt joints

Type of welded joint for test assembly				Range of approval
Butt welding	One side	With backing	A	A,C,D
		Without backing	B	A,B,C,D
	Both sides	With gouging	C	C
		Without gouging	D	C,D

2.15.8 **Range of material types**:

(a) A qualification test performed on one strength level of steel may be used to weld all similar materials with the same or lower specified minimum yield stress with the exception of the two-run (T) or high welding heat input (A) techniques where acceptance is limited to the strength level used in the test. Similarly, a qualification test performed on a steel with one toughness level may be considered acceptable for welding all similar materials with the same or three toughness grades lower specified minimum toughness level.

(b) A qualification test performed on H47 strength grade steels may be used to weld the steel of the same strength level or grade H40 and all lower toughness grades to that tested.

(c) For high strength quenched and tempered steels, for each strength level, welding procedures are considered applicable to the same and lower toughness grades as that tested. For each toughness grade, welding procedures are considered applicable to the same and one lower strength level as that tested. The approval of quenched and tempered steels does not qualify thermo-mechanically rolled steels (TMCP steels) and vice versa.

(d) For weldable C and C-Mn steel forgings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel forgings does not qualify other delivery conditions and vice versa.

(e) For weldable C and C-Mn steel castings, welding procedures are applicable to the same and lower strength level as that tested. The approval of quenched and tempered steel castings does not qualify other delivery conditions and vice versa.
Dissimilar materials. Where a qualification test has been performed using dissimilar materials, acceptance is to be limited to the materials used in the test.

2.15.9 **Thickness and diameter range**:

(a) For straight butt welds, the material thickness range to be approved is to be based on the thickness of the test piece and the type of weld as shown in Table 12.2.5.

(b) For butt welds between plates of unequal thickness, the lesser thickness is the ruling dimension.

(c) For fillet welds and 'T' butt welds, Table 12.2.5 is to be applicable to both the abutting and through member thicknesses. In addition to the requirements of Table 12.2.5, the range of approval of throat thickness '*a*' for fillet welds is to be as follows:
   - single run: 0,75*a* to 1,5*a*
   - multi-run: as for butt welds with multi-run (i.e. $a = t$)

(d) Notwithstanding any of the above, the approval of maximum thickness of base metal for any technique is to be restricted to the thickness of the test assembly if three of the hardness values in the heat affected zone are found to be within 25 Hv of the maximum permitted.

(e) The material diameter range to be approved is to be based on the diameter of the test piece and type of weld as shown in Table 12.2.6.

2.15.10 **Welding consumables**:

(a) For manual and semi-automatic welding used for the fill and capping weld runs, it may be acceptable to change the brand or trade name of the welding electrode or wire from that used in the test, provided the proposed alternative has the same or higher approval grading and the same flux type (e.g. basic low hydrogen, rutile, etc.) as used in that test.

(b) For the consumable used to make the root weld of full penetration butt welds made from one side only, no change in the type or trade name of the consumable or backing material is permitted. Alternative backing materials may be used provided they are equivalent to those used for approval. Where the approved backing material is a low hydrogen grade and the steel being welded requires a low hydrogen backing material, testing of the alternative backing material is to confirm compliance with the requirements of Ch 11,7

(c) For processes with heat input over 5 kJ/mm, no change in the type or trade name of the consumable is permitted.

2.15.11 **Shielding gas**. For gas shielded welding processes, a change in shielding gas composition from that used in the test will require a new qualification test.

Table 12.2.5 Welding procedure thickness approval range – Butt welds

Test thickness, *see* Note 1 (t in mm)	Range approved	
	All multi-run butt welds and all fillet welds *see* Notes 3 and 4	All single-run or two-run two-run (T technique) butt welds
$t \le 3$	t to $2t$	$0,7t$ to $1,1t$
$3 < t \le 12$	3 to $2t$	$0,7t$ to $1,1t$
$12 < t \le 100$	$0,5t$ to $2t$, *see* Note 2	$0,7t$ to $1,1t$ *see* Note 5
$t > 100$	$0,5t$ to $1,5t$	$0,7t$ to $1,1t$ *see* Note 5

NOTES
1. Where the test plates have dissimilar thickness, the thickness, t, is to be based on the minimum thickness for butt welds and the maximum thickness for fillet welds.
2. Subject to a maximum limit of 150 mm.
3. For multi process procedures, the recorded thickness contribution of each process is to be used as a basis for the range of approval of the individual welding process.
4. For vertical down welding, the test piece thickness, t, is the upper limit of the range of application.
5. For processes with heat input over 5,0 kJ/mm, the upper limit of the range of approval is to be 1,0 t.

Table 12.2.6 Diameter range approved

Diameter used for test, *see* Note 1	Range of diameters approved
$D \le 25$ mm	$0,5D$ to $2D$
$D > 25$ mm	$> 0,5D$, *see* Note 2

NOTES
1. D is the outside diameter of the pipe or the smallest side dimension of rectangular hollow section.
2. Lower diameter range limited to 25 mm minimum.

2.15.12 **Heat Input**. The upper limit of heat input approved is 25 per cent greater than that used in the test, or 5,5 kJ/mm, whichever is the smaller. With heat input over 5,0 KJ/mm, the upper limit is 10 per cent above that used in the test. In all cases, the lower limit of heat input approved is 25 per cent lower than that used in the test.

2.15.13 **Current type**. The current type used during the qualification test is to be the only type approved. Additionally, changes from or to pulsed current require new qualification tests.

2.15.14 **Preheat temperature**. The temperature used during the test is to be the minimum approved. Higher temperatures may be specified for production welds up to the maximum interpass temperature. Where hardness tests have been performed that exhibit results near the maximum permitted, an increase in preheat temperature is required when welding material of greater thickness than that used in the test.

2.15.15 **Interpass temperature**. The maximum interpass temperature recorded during qualification testing is to be the maximum approved. Lower temperatures may be specified for production welding, but no lower than the minimum preheat temperature.

2.15.16 **Post-weld heat treatment**. A qualification test performed with no post weld heat treatment is only acceptable for production welding where no heat treatment is applied. Where the qualification test has included a post weld heat treatment, this is to be applied to all welds made with the welding procedure. The average specified soak temperature may vary by up to 25°C from that tested.

2.15.17 **Shop primers.** Welding procedure qualification with shop primers qualifies welds without primer, but not vice versa.

2.16 Welding procedure specification (WPS)

2.16.1 A welding procedure specification (WPS) is to be prepared by the manufacturer detailing the welding conditions and techniques to be employed for production welding. The WPS is to be based on the conditions and variables used during the qualification test, and is to include all the ranges of the essential variables specified in 2.2.1 and 2.15.

2.16.2 The WPS should reference the procedure qualification record upon which it is based and is to be approved by the Surveyor prior to commencing production welding.

■ *Section 3* Specific requirements for stainless steels

3.1 Scope

3.1.1 The requirements of this Section relate to the group of steel materials classed as stainless steels and include austenitic and duplex grades and martensitic grades.

3.1.2 In all cases, welding procedure tests are to be performed generally in accordance with Section 2 with the specific requirements specified below.

3.2 Austenitic stainless steels

3.2.1 The requirements of this Section relate to the group of stainless steel materials that are austenitic at ambient and sub-zero temperatures, (e.g., 304L, 316L types), *see* Table 3.7.1 in Chapter 3.

3.2.2 Impact tests are to be performed from specimens removed from the weld metal. Tests in the heat affected zone are not required.

3.2.3 Hardness tests are generally not required.

3.2.4 For cryogenic or corrosion resistant applications, the ferrite content in the weld cap region is to be measured and is to be in the range 2 to 10 per cent, with the exception of grades S 31245 and N 08904 where the content is to be nominally zero.

3.2.5 A qualification test performed on an austenitic grade may be considered acceptable for welding other austenitic steels with the same or lower level of alloying elements and the same or lower tensile strength.

3.2.6 A qualification test performed for cryogenic applications may be considered acceptable for chemical applications, but not vice versa.

3.3 Duplex stainless steels

3.3.1 The requirements of this Section relate to the group of stainless steel materials that have a ferritic-austenitic structure and are usually referred to as duplex or super duplex stainless steels (e.g.,S 31803, S 32760).

3.3.2 Impact test specimens are to be removed from the weld and heat affected zone in accordance with Section 2 with the exception that impact test specimens notched at the FL + 10 mm location are not required. The specimens are to be tested at a temperature of –20°C or the minimum design temperature whichever is the lower and exhibit a minimum average energy of 40 J.

3.3.3 The corrosion resistance is to be maintained in the welded condition and the following tests are to be performed to demonstrate acceptable resistance, unless agreed otherwise.

(a) A sample is to be removed from the weld and heat affected zone for micro-structural examination and is to be suitably prepared and etched so that the micro-structures of the weld and heat affected zones can be examined at a magnification of x200 or higher. The micro-structure of the weld and heat affected zone is to be examined, the percentage grain boundary carbides and intermetallic precipitates is to be reported.

(b) The ferrite content in the un-reheated weld cap and cap HAZ along with the weld root and root HAZ are to be measured and reported. The ferrite content is to be in accordance with Table 12.3.1. Where the intended construction is such that the corrosion medium is only in contact with one surface of the weld (i.e., the weld root), the ferrite determination need only be reported in that surface area.

(c) Corrosion testing is to be performed on samples removed from the weld such that both the weld and HAZ are included in the test. The critical pitting temperature is to be determined in accordance with ASTM G48 Method C and meet the requirements specified in Table 12.3.1. The cap and root surfaces are to be inspected for evidence of pitting and may require probing the surface with a needle. Pitting found on the ends of the specimen in the weld cross-section may be ignored. The use of the weight loss method for corrosion testing may be accepted subject to special consideration.

Table 12.3.1 Requirements for ferrite content and corrosion tests for duplex stainless steel test welds

Duplex Stainless Steel Material Grade	Weld and HAZ Ferrite content	Minimum Critical Pitting Temperature (CPT)
S 31260	30 to 70%	20°C
S 31803	30 to 70%	20°C
S 32550	35 to 65%	25°C
S 32750	35 to 65%	25°C
S 32760	35 to 65%	25°C

3.3.4 Where the test weld is between a grade of carbon steel and duplex stainless steel, the test requirements of 3.3.3(a) and (c) are not required and the ferrite content of the weld and the duplex heat affected zone are to be reported for information.

3.3.5 A qualification test performed on a duplex stainless steel grade may be considered acceptable for welding other duplex grades which have the same or less stringent mechanical or corrosion properties.

3.3.6 The range of heat input is not to vary by more than +10 per cent or –25 per cent from that used during testing.

3.4 Martensitic stainless steels

3.4.1 The requirements of this Section relate to the group of stainless steel materials that have a martensitic structure at ambient temperatures, *see* Table 4.5.1 in Chapter 4.

3.4.2 The results of the hardness survey results are to be reported for information purposes only.

3.4.3 A qualification test is considered acceptable only for the grade of material used in the test.

■ *Section 4*
Welding procedure tests for non-ferrous alloys

4.1 Requirements for aluminium alloys

4.1.1 The requirements for welding procedure qualification tests for aluminium alloys are to be in accordance with the general requirements of Section 2 with the following exceptions and specific requirements.

4.1.2 Non-destructive examination is to be performed in accordance with 2.5 and the assessment of results is to be in accordance with Table 12.4.1 and Table 12.4.2.

4.1.3 Acceptance of the mechanical tests is to be in accordance with Ch 11,9. Welding of the strain hardened and heat treatable aluminium alloys will generally result in a loss of tensile strength in the heat affected zone below that specified for the base materials and the tensile strength acceptance criteria to be applied is that specified for the material in the annealed or 'as fabricated' condition. Minimum values of tensile strength measured on the transverse tensile samples are given in Table 12.4.3.

4.1.4 Impact tests and hardness surveys are not required for aluminium alloys.

4.1.5 Four side bend tests may be used in place of root and face bends where the test thickness exceeds 12 mm, and longitudinal bend tests may be used instead of transverse tests where the test weld is between different grades of alloy. Bend specimens are to be bent round a former in accordance with Table 11.9.1 in Chapter 11, with the exception that the 6000 series alloys may be bent round a former with D/t = 7.

4.1.6 The ranges of approval to be applied to the WPS are to be as specified for steel in 2.15 with the following exceptions:

(a) The welding positions approved are as detailed in Table 12.4.4.
(b) The aluminium alloys are grouped into three groups as follows:
   - Group A: aluminium-magnesium alloys, with Mg content ≤3,5 per cent (alloy 5754).
   - Group B: aluminium-magnesium alloys with 4 per cent ≤Mg ≤5,6 per cent (alloys 5059, 5083, 5086, 5383 and 5456).
   - Group C: aluminium-magnesium-silicon alloys (alloys 6005A, 6061 and 6082). For each group, the qualification made on one alloy qualifies the procedure also for the other alloys in the group, with equal or lower tensile strength after welding. The qualification made on group B alloys qualifies the procedure for Group A alloys also. Approval for the range of material grades is summarised in Table 12.4.5.

Table 12.4.1 Acceptance criteria for surface imperfections of aluminium alloys

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0,1s$ or $0,1a$ max. 1,0 mm
Uniformly distributed porosity (*see* Note 1)	2012	≤ 0,5% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	Not permitted
Intermittent undercut	5012	$h \leq 0,1t$ or 0,5 mm (whichever is the lesser)
Excess weld metal (*see* Note 2)	502	$h \leq$ 1,5 mm + $0,1b$ or 6 mm (whichever is the lesser)
Excess penetration	504	$h \leq$ 4 mm
Root concavity (*see* Note 2)	515	$h \leq 0,05t$ or 0,5 mm (whichever is the lesser)
Linear misalignment (*see* Notes 3 and 4)	507	$h \leq 0,2t$ or 2,0 mm (whichever is the lesser)
Symbols		
a = nominal throat thickness of a fillet weld b = width of weld reinforcement d = diameter of a gas pore h = height or width of an imperfection s = nominal butt weld thickness t = wall or plate thickness (nominal size)		

NOTES
1. To be in accordance with EN ISO 10042.
2. A smooth transition is required.
3. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is to be taken when the centrelines coincide.
4. Dimensional tolerances not specified in these Rules are to be mutually agreed between the manufacturer and the Surveyor.

Table 12.4.2 Acceptance criteria for internal imperfections of aluminium alloys

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2011	$d \leq 0{,}2s$ or $0{,}2a$ or 4 mm (whichever is the lesser)
Linear porosity (*see* Note 2)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	$0{,}5t$ to $3t$ ≤ 1% of area $> 3t$ to $12t$ ≤ 2% of area $> 12t$ to $30t$ ≤ 3% of area $> 30t$ ≤ 4% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 15$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0{,}2s$ or $0{,}2a$ or 3 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0{,}2t$ or $0{,}2a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size), in mm
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. For this acceptance criterion, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.

Table 12.4.3 Tensile strength requirements by grade for aluminium alloys

Parent material Grade (alloy designation)	Minimum tensile strength (N/mm^2)
5754	190
5086	240
5083	275
5383	290
5059	330
5456	290
6005A	170
6061	170
6082	170

(c) The qualification of a procedure carried out on a test assembly of thickness t is valid for the thickness range given in Table 12.4.6. In the case of butt joints between dissimilar thicknesses, t is the thickness of the thinner material. In the case of fillet joints between dissimilar thicknesses, t is the thickness of the thicker material. In addition to the requirements of Table 12.4.6, the range of the qualification of throat thickness of fillet welds, a, is given in Table 12.4.7. Where a fillet weld is qualified by a butt weld test, the throat thickness range qualified is to be based on the thickness of the deposited weld metal.

Table 12.4.4 Welding procedure approval, welding positions for aluminium alloys

Test position		Positions approved
Downhand	D	D
Horizontal-vertical	X	D, X
Vertical up	Vu	D, X, Vu
Overhead	O	D, X, Vu and O

NOTE
Welding in vertical down (Vd) position is not recommended.

(d) The range of shielding gas compositions approved is to be in accordance with Table 11.9.2 in Chapter 11.

(e) A change in the brand or trade name of the filler metal from that used in the test is acceptable, provided that the proposed consumable has the same or higher strength grading.

(f) A change in post-weld heat treatment or ageing is not permitted, except that for the heat treatable alloys, artificial ageing may give approval for prolonged natural ageing.

Table 12.4.5 Welding procedure approval, aluminium material grades approved

Material used in qualification test	Material Grades approved				
5754	5754				
5086	5086	5754			
5083	5083	5086	5754		
5383	5383	5083	5086	5754	
5059	5059	5383	5083	5086	5754
5456	5456	5383	5083	5086	5754
6005A	6005A	6082	6061		
6082	6005A	6082	6061		
6061	6005A	6082	6061		

NOTE
Approval includes all the different strained and tempered conditions in each case.

Table 12.4.6 Range of qualification for parent material thickness

Thickness of test assembly, t (mm)	Range of qualification Multi pass welds	Range of qualification All single-run or two-run (T technique) butt welds
$t \leq 3$	0,5 to $2t$	$0{,}5t$ to $1{,}1t$
$3 < t \leq 20$	3 to $2t$	$0{,}5t$ to $1{,}1t$
$t > 20$	$\geq 0{,}8t$	$0{,}5t$ to $1{,}1t$

Table 12.4.7 Range of qualification of throat thickness for fillet welds

Throat thickness of test piece, a (mm)	Range of qualification
$a < 10$	0,75 a to 1,5 a
$a \geq 10$	$\geq 7{,}5$

4.2 Requirements for copper alloys

4.2.1 The requirements for welding procedure qualification tests for copper alloys are to be in accordance with the requirements for steel as given in Section 2 with the following exceptions and additions.

4.2.2 Impact tests on copper alloys are not required.

4.2.3 Hardness tests are not required for seawater service.

4.2.4 For the welding of cast copper alloys for propellers, the minimum tensile strength from the transverse tensile test is to be in accordance with Table 12.4.8.

4.2.5 Bend tests are to be performed over a diameter of former as detailed in Table 12.4.9.

Table 12.4.8 Minimum transverse tensile strengths for welded copper alloy propellers

Alloy designation	Minimum tensile strength (N/mm^2)
CU 1	370
CU 2	410
CU 3	500
CU 4	550

4.2.6 The range of approval to be applied to the WPS is to be as specified in 2.15 with the exception of the material grades which are detailed in Table 12.4.10.

Table 12.4.9 Former diameters for bend testing of copper alloy welds

Alloy designation (*see* Chapter 9)	Former diameter (*D/t*)
Cast propellers:	
CU1	4
CU2	4
CU3	6, *see* Note
CU4	6, *see* Note
Other short freezing range castings:	
Copper-Nickel 90/10	4
Copper-Nickel 70/30	4
Aluminium bronze	6
Wrought alloys (tubes and pipes):	
Copper-phosphorus	3
Aluminium-brass	3
90/10 Copper-nickel-iron	3
70/30 Copper-nickel-iron	3

NOTE
Where the qualification tests for these alloys are subjected to post-weld heat treatment the former diameter may be increased to *D/t* = 10.

Table 12.4.10 Range of approval for copper alloy material grades

Category	Alloy grade used in the qualification test	Alloy grades approved
Propellers	CU1 CU2 CU3 CU4	CU1 CU1 and CU2 CU1, CU2 and CU3 CU4 *see* Note 1
Tubes/pipes	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron	90/10 Copper-Nickel-Iron 70/30 Copper-Nickel-Iron and 90/10 Copper-Nickel-Iron
Tubes/pipes *see* Note 2	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass	Copper-Phosphorus deoxidised – arsenical Copper-Phosphorus deoxisised – non arsenical Aluminium-brass

NOTES
1. Where a CU3 type welding consumable has been used for the qualification test, the range of approval may also include welding of CU3.
2. These grades have limited weldability and approval to weld is subject to the materials satisfying the requirements of Table 9.3.1 in Chapter 9.

■ *Section 5*
Welder qualification tests

5.1 Scope

5.1.1 The requirements of this Section relate to qualification of welders involved in welded construction associated with ships, or other marine structures, and products or components intended for use on or in these structures.

5.1.2 The requirements relate to fusion welding processes that are designated as manual, semi-automatic or partly mechanised. Special consideration will be given to other welding processes adapted from these requirements.

5.1.3 Prior to commencing production welding, the welder is to have performed a qualification test that satisfies these requirements. It is the responsibility of the manufacturer to ensure that the welder possesses the required level of skill for the work to be undertaken.

5.1.4 The qualification of welders is to be documented by the manufacturer and the records are to be available for review by the Surveyor.

5.1.5 Welder qualification tests made in accordance with EN, ISO, JIS, ASME or AWS may be considered for acceptance provided that, as a minimum, they are equivalent to, and meet the technical intent of these Rules to the satisfaction of the Surveyor.

5.2 Welder qualification test assemblies

5.2.1 The welding of the welder qualification test assembly is to simulate, as far as practicable, the conditions to be experienced in production and be witnessed by the Surveyor. The test is to be carried out on a test assembly piece and not by way of production welding.

5.2.2 The test is to simulate, as far as practicable, the welding techniques and practices to be encountered during production welding. The test assembly is to be designed to test the skill of the welder and have the shape and dimensions appropriate to the range of approval required.

5.2.3 The inspection length of the test weld is to be such as to permit the removal of all the necessary test specimens and for plate tests, but in no case is to be less than 250 mm. The test assembly is to be set in one of the positions as shown in Fig. 12.2.2 appropriate to the welding positions to be approved.

5.2.4 A welding procedure specification (WPS) is required for the execution of the qualification test and is to include the information specified in 2.2.1, as a minimum.

5.2.5 The test assembly is to be marked with a unique identification and the inspection length is to be identified prior to commencing welding. For pipe welds, the whole circumference is to be considered as the inspection length.

5.2.6 During welding of the test assembly, the welding time is to be similar to that expected under production conditions. For manual or semi-automatic processes, at least one stop and re-start in the root and in the top surface layer is to be included in the inspection length and marked for future inspection.

5.2.7 During welding of the test assembly, minor imperfections may be removed by the welder by any method that is used in production, except on the surface layer.

5.2.8 The Surveyor may stop the test if the welding conditions are not correct or if there is any doubt about the competence of the welder to achieve the required standard.

5.3 Examination and testing

5.3.1 Each completed test weld is to be examined and tested in accordance with the requirements of Table 12.5.1.

5.3.2 Visual examination is to be performed in the as welded state prior to any other assessment.

5.3.3 For plate butt welds, fracture testing may be used in place of radiography.

5.3.4 Where a backing strip has been used, it is to be retained for non-destructive examinations, but is to be removed prior to performing any bend or fracture tests.

5.3.5 Where fracture tests are required, they are to sample as much of the inspection length as practicable and the test assembly may be cut into several test specimens to achieve this. Testing is to be performed as shown in Figs. 12.5.1(a) or 12.5.1(b).

5.3.6 For butt weld tests in aluminium alloys both radiography and bend tests are required.

5.3.7 When bend tests are required, 2 root and 2 face bends are to be tested and where the test thickness exceeds 12 mm, these may be substituted by 4 side bends specimens. The diameter of former to be used is to be in accordance with that specified for welding procedure qualification testing given in 2.7.6(a).

5.3.8 Where macro examination is required, the specimen is to be polished and etched to reveal the weld runs and heat affected zones, and be examined at a magnification between x5 and x10.

5.4 Acceptance criteria

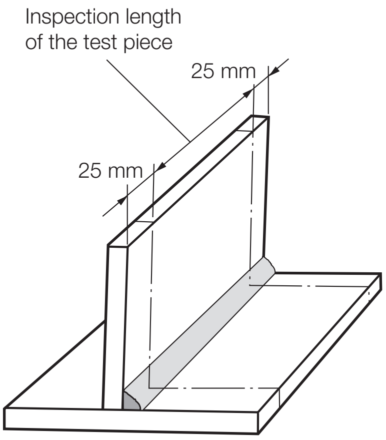
5.4.1 The acceptance criteria are to be in accordance with 2.5.5.

5.4.2 Fracture tests and macro-sections are to be assessed in accordance with the non-destructive examination acceptance criteria.

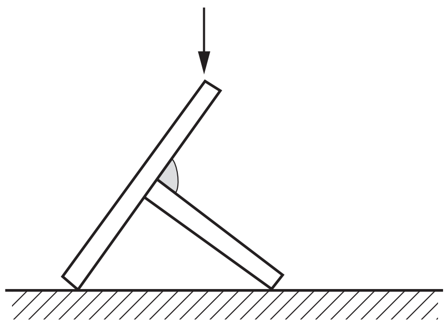
Table 12.5.1 Welder qualification test requirements

Examination type	Butt welds	Fillet welds	Pipe branch welds
Visual	100%	100%	100%
Surface crack detection	*See* Note 1	100%	100%
Radiography	100% *See* Notes 2 and 6	Not required	Not required
Bend tests	4 required *See* Notes 3 and 6	Not required	Not required
Fracture tests	Not required	1 required *See* Note 4	Not required
Macro	Not required	1 required *See* Note 4	4 required *See* Note 5

NOTES
1. Surface crack detection examination may be required by the Surveyor in order to clarify the acceptability of any weld feature.
2. Radiography may be replaced by ultrasonic examination for carbon and low alloy steels where the thickness exceeds 8 mm.
3. Bend tests are required for gas metal arc welding with solid wire (GMAW) and oxy-acetylene welding.
4. The fracture test may be replaced with 4 macro sections equally spaced along the inspection length.
5. Macro-sections are to be separated by 90° measured around the abutting pipe member.
6. Radiography and bend tests are required for tests in aluminium alloys.



(a)
Sectioning into an even-numbered quantity of test specimens



(b)
Fracture testing
(The fillet weld may be notched if necessary)

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Fig. 12.5.1(a) Preparation and fracture testing of test specimens for a fillet weld in plate

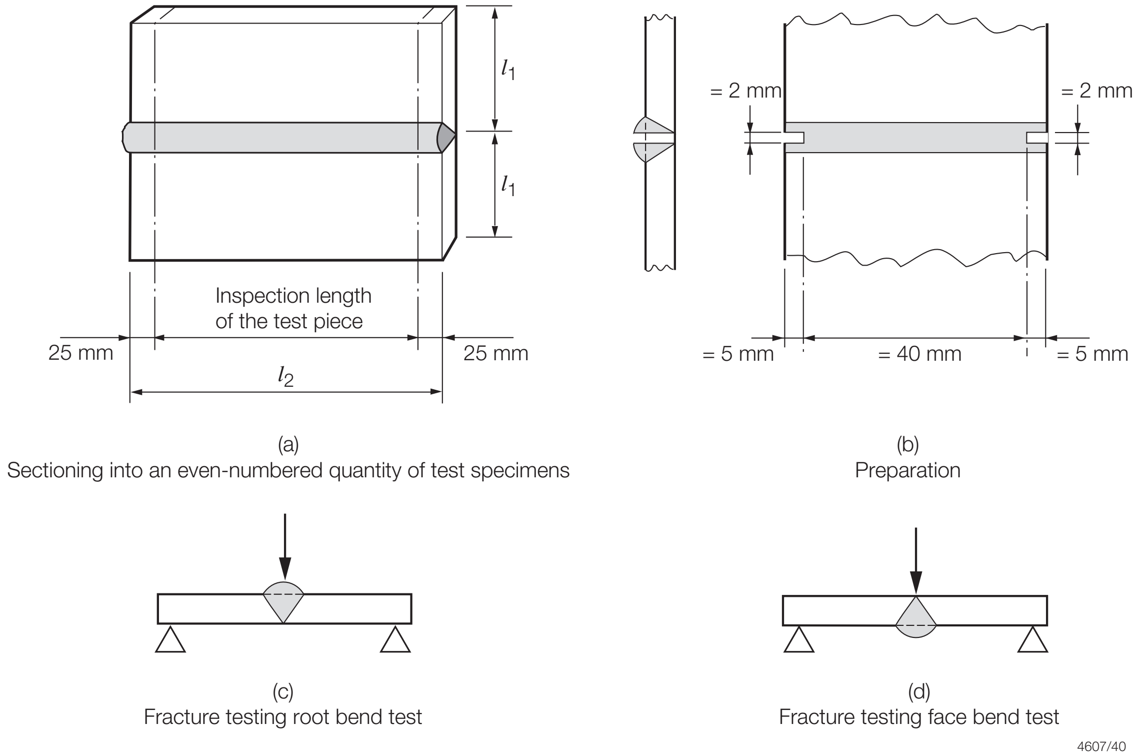
5.4.3 Bend tests are considered acceptable if after bending through an angle of at least 180°, there are no defects on the tension side of the specimen greater than 3 mm in any direction.

5.5 Failure to meet requirements

5.5.1 Where a macro-section fails to meet requirements, one additional specimen may be removed from the test assembly and examined.

5.5.2 Where a bend or fracture test specimen fails to meet requirements, two additional specimens may be prepared from the same test assembly. If there is insufficient material, the welder may be permitted to weld an additional assembly to the same WPS, at the discretion of the Surveyor.

5.5.3 Where any of the additional test specimens fails to satisfy the requirements, the test will be considered as not meeting the requirements.



(a)
Sectioning into an even-numbered quantity of test specimens

(b)
Preparation

(c)
Fracture testing root bend test

(d)
Fracture testing face bend test

Fig. 12.5.1(b) Preparation and fracture testing of test specimens for a butt weld in plate

5.5.4 Where a test fails to comply with the acceptance criteria, the welder may be permitted to weld a second test piece. If this does not meet requirements, the welder is to be considered as not being capable of achieving the requirements.

5.6 Range of approval

5.6.1 Upon successful completion of all the necessary examinations and tests, the welder is to be considered qualified. The essential variables and the range of welding conditions for which the welder is considered approved are specified in the following paragraphs.

5.6.2 Welding variables such as preheat, interpass temperature, heat input and current type are not considered welder qualification variables. However, if the WPS used for testing specify these, they are to be included in the test and the welder is expected to follow the specific instructions.

5.6.3 Where the WPS used for the welder qualification test specifies post weld heat treatment, this need not be applied to the test weld unless bend tests are required and the material exhibits low ductility in the as welded condition.

5.6.4 The qualification test performed by a manufacturer is only applicable to workshops under the same technical control and quality system as that used for the test.

5.6.5 The welding process used in the qualification test is the process approved. However, it is possible for the welder to use more than one process in the test and the range of approval that may be applied to each will be within the limits of the essential variables appropriate to the part of the test where each welding process was used.

5.6.6 Material types are to be grouped as shown in Table 12.5.2 for welder qualifications. A qualification test performed on one material from a group will permit welding of all other materials within the same group. In addition, qualification on one group of materials may confer approval to weld other groups as shown in Table 12.5.3.

5.6.7 A qualification test performed on one thickness will confer approval to weld other thicknesses as specified in Table 12.5.4. Where welding is required between materials of different thickness, the reference thickness for approval purposes is to be the lesser thickness.

5.6.8 A qualification test performed on plate confers approval to weld on pipes having an outside diameter greater than 500 mm in a fixed position (*see* Table 12.5.5 and Table 12.5.6).

5.6.9 A qualification test performed using a specific diameter of pipe will give approval to weld other diameters as shown in Table 12.5.5. For branch welds, the diameter upon which approval is based is to be the branch member.

5.6.10 A qualification test performed on a butt weld may be considered as giving approval for fillet welds.

Table 12.5.2 Welder qualification materials groupings

Material group	Material description	Typical LR Grades	Rules for Material references
WQ 01	Low carbon unalloyed, C/Mn, or Low alloyed steels (Re ≤ 360 N/mm^2)	A, B, D and E AH to FH32 and 36 Boiler 510FG and lower LT-AH to FH32 and 36 U1 and U2 Steel castings Steel pipes	Ch 3,2 Ch 3,3 Ch 3,4 Ch 3,6 Ch 3,9 and Ch 10 Ch 4,2, 3, 6 and 7 Ch 6,2, 3, 4 and 6
WQ 02	Cr-Mo, or Cr-Mo-V creep resisting steels	13CrMo45 and 11CrMo910 1Cr½Mo and 2¼Cr1Mo ½Cr½Mo¼V	Ch 3,4 Ch 4,6 and Ch 6,2, 3 and 6 Ch 4,6 and Ch 6,2
WQ 03	High strength fine grained, Normalised or quenched, or Tempered structural steels (2,0 – 5% Ni, with Re > 360 N/mm^2)	AH to FH40 to 69 LT-AH to LT-FH40 1½ , 3½ Ni steels and castings U3, R3, R3S and R4	Ch 3,3 and 10 Ch 3,6 Ch 3,6, Ch 4,7 and Ch 6,4 Ch 3,9 and Ch 10
WQ 04	Ferritic, or martensitic stainless steels (12 to 20% Cr)	13% Cr (martensitic)	Ch 4,5 (martensitic)
WQ 05	Ferritic low temperature steels	5Ni and 9Ni	Ch 3,6
WQ 011	Ferritic-austenitic stainless steels, Austenitic stainless steels, or Cr-Ni steels	304, 316, 317, 321 and 347 S31260, S31803, S32550 and S32750	Ch 3,7 and 8 Ch 4,8 and Ch 6,5
WQ 22a	Aluminium alloy – Non-heat treatable Mg < 3,5%	5754	Chapter 8
WQ 22b	Aluminium alloy – Non-heat treatable 3,5% < Mg < 5,6%	5083 and 5086	Chapter 8
WQ 23	Aluminium alloy – Heat treatable	6005-A, 6061 and 6082	Chapter 8
WQ 30	Copper alloys for propellers – Manganese bronze	Cu1	Ch 9,1
WQ 31	Copper alloys for propellers – Nickel-manganese bronze	Cu2	Ch 9,1
WQ 32	Copper alloys for propellers – Nickel-aluminium bronze	Cu3	Ch 9,1
WQ 33	Copper alloys for propellers – Manganese-aluminium bronze	Cu4	Ch 9,1
WQ 34	Copper alloys for tubes – Copper phosphorus	Deoxidised – non-arsenical and arsenical	Ch 9,3
WQ 35	Copper alloys for tubes – Aluminium brass	Aluminium brass	Ch 9,3
WQ 36	Copper alloys for tubes – Copper-nickel-iron	70/30 Cu/Ni and 90/10 Cu/Ni	Ch 9,3

5.6.11 A butt qualification test welded from one side, with the root unsupported (i.e., no backing), will give approval for welds made from both sides with or without back gouging or grinding, but not vice versa.

5.6.12 A qualification test performed in one position will give approval to weld in other positions as shown in Table 12.5.6.

5.6.13 For manual metal arc welding with covered electrodes, a qualification test performed using an electrode with one type of coating will only be approved for welding with that type of coating. However, a qualification test performed using a basic low hydrogen type coating will confer approval to use electrodes with rutile coatings.

Table 12.5.3 Welder qualification, range of approval for material groups

Material group used for testing	Material groups approved to weld			
WQ 01	WQ 01			
WQ 02	WQ 01	WQ 02		
WQ 03	WQ 01	WQ 02	WQ 03	
WQ 04	WQ 01	WQ 02	WQ 04	
WQ 05	WQ 05			
WQ 11	WQ 11	WQ 05, *see* Note	WQ 04, *see* Note	
WQ 22a	WQ 22a	WQ 22b		
WQ 22b	WQ 22a	WQ 22b		
WQ 23	WQ 22a	WQ 22b	WQ 23	
WQ 30	WQ 30	WQ 31	WQ 32	WQ 33
WQ 31	WQ 30	WQ 31	WQ 32	WQ 33
WQ 32	WQ 30	WQ 31	WQ 32	WQ 33
WQ 33	WQ 30	WQ 31	WQ 32	WQ 33
WQ 34	WQ 34	WQ 35		
WQ 35	WQ 34	WQ 35		
WQ 36	WQ 36			

NOTE
Provided an austenitic welding consumable compatible with material group WQ 11 is used.

Table 12.5.4 Welder qualification, range of approval for material thickness

Material type	Test piece thickness (mm)	Range approved, *see* Note (mm)
Steel and copper alloys	$t \leq 3$ $3 < t \leq 12$ $t > 12$	t to $2t$ 3,0 to $2t$ $\geq 5,0$
Aluminium alloys	$t \leq 6$ $6 < t \leq 15$ $t > 40$ mm	0,7 to $2,5t$ $6,0 < t \leq 40,0$ 41 to $2t$

NOTE
For oxy-acetylene welding the maximum thickness is limited to 1,5 t.

Table 12.5.5 Welder qualification, diameter range of approval for pipes and hollow sections

Material type	Test piece diameter (mm)	Range approved (mm)
Steel and copper alloys	$D \leq 25$ $25 < D \leq 150$ $D > 150$ Plate, *see* Note 2	D to $2D$ $0,5D$ to $2D$, *see* Note 1 $\geq 0,5D$ ≥ 500
Aluminium alloys	$D \leq 125$ $D > 125$ Plate, *see* Note 2	$0,25D$ to $2D$ $\geq 0,5D$ ≥ 500

NOTES
1. Subject to 25 mm minimum diameter.
2. Plate qualification will approve welding on pipes greater than 150 mm diameter when the pipe is rotated.

Table 12.5.6 Welding position ranges for welder qualification

Test weld conditions		Positions qualified			
		Plate		Pipe, *see* Note 1	
Type of weld	Test position	Butt weld	Fillet weld	Butt weld	Fillet weld
Plate butt, *see* Note 5	D	D	D	D	D
	X	D,X	D, X	D	D, X
	Vu	D, Vu	D, X, Vu	D	D, Vu
	Vd	Vd	Vd	—	—
	O	D, X, Vu, O	D, X, Vu, O	D	D, X, Vu, O
Plate Fillet, *see* Note 5	D	—	D	—	D
	X	—	D, X	—	D, X
	Vu	—	D, X, Vu	—	D, X, Vu
	Vd	—	Vd	—	—
	O	—	D, X, Vu, O	—	D, X, Vu, O
Pipe butt	D	D	D, X	D	D, X
	X	D, X	D, X	D, X	D, X
	D+Vu+O, *see* Note 3	D, Vu, O	D, X, Vu, O	D, Vu, O	D, X, Vu, O
	D+Vd+O, *see* Notes 2 and 3	Vd	Vd	Vd	Vd
	Axis at 45°, *see* Note 4, Travel Vu	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O	D, X, Vu, O
	Axis at 45°, *see* Notes 2, 3 and 4, Travel Vd	Vd	Vd	Vd	Vd
Pipe fillet	D	—	D	—	D
	X	—	D, X	—	D, X
	D+Vu+O *see* Note 3	—	D, X, Vu, O	—	D, X, Vu, O
	D+Vd+O *see* Note 3	—	Vd	—	Vd

NOTES
1. Pipe D position means pipe in horizontal position and rotated, *see* Fig. 12.2.2(b) and Fig. 12.2.2(d).
2. Vd position not usually recommended for pipe welds less than 500 mm diameter.
3. Pipe fixed with axis in the horizontal position (e.g. ASME 5G).
4. Pipe fixed with axis at 45° to the horizontal (e.g. ASME 6G).
5. Plate qualification tests confers approval to weld pipes with diameter greater than 500 mm.

5.6.14 For gas shielded welding processes that use a single component shielding gas, no change to the gas composition is permitted from that tested. Where the test has used a two component shielding gas, a change in the ratio of component gases is permitted, provided that one of the components is not reduced to zero. Where the test has used a three component shielding gas, changes are permitted in the ratio of component gases and the gas with the smallest ratio may be reduced to zero, provided this does not change the shielding gas from an active one to an inert one or vice versa. In addition, where a change in shielding gas composition requires a different welding method or technique to be employed, a new qualification test will be required.

5.6.15 A change of welding flux from that used for the test is permitted.

5.7 Welders qualification certification

5.7.1 All the relevant conditions used during the test are to be entered on the welder's qualification certificate along with the permitted range of approval.

5.7.2 If the Surveyor is satisfied that the welder has demonstrated the appropriate level of skill and all tests are satisfactory, the Surveyor will endorse the certificate verifying that the details contained on it are correct and that the test welds were prepared, welded and tested in accordance with the specified Rules, Codes or Standards.

5.7.3 The welder is considered to be approved for an initial validity period of 2 years. The welder is considered to have retained the qualification subject to the manufacturer confirming every 6 months that the welder has used the welding process with acceptable performance in the preceding 6 months.

5.7.4 After 2 years, the Surveyor may extend the validity of the approval for another period of two years provided that records or documented evidence is made available confirming acceptable welding performance, within the original range of approval, without a break exceeding 6 months. The Surveyor will signify acceptance of the extension to the validity by endorsing the certificate.

5.7.5 Where there is any reason to question the welder's ability, or there is a lack of continuity in the use of the welding process, or insufficient recorded evidence of acceptable weld performance, the welder is to perform a new qualification test.

5.7.6 Where the manufacturer has existing welders that have previously performed qualification tests, these may be considered for acceptance provided they satisfy the above requirements and the tests have been performed in the presence of an independent examiner that is acceptable to the Society.

5.7.7 Not withstanding the above, the Surveyor may at any time request a review of a welder's qualification records. If there is any reason for doubt concerning the skill of the welder, the Surveyor may withdraw the qualification and require a re-qualification test to be performed.

Requirements for Welded Construction

■ *Section 1* General welding requirements

1.1 Scope

1.1.1 This Chapter specifies requirements for fabrication and welding during construction and repair of ships or other marine structures, and their associated pressure vessels, machinery, equipment, components and products intended for use in these structures.

1.1.2 The requirements relate to fusion welding. Special consideration will be given to the use of other welding processes based on these requirements.

1.1.3 It is the responsibility of the manufacturer to ensure compliance with all aspects of these Rules and inform the Surveyor of any deviations that have occurred. All deviations are to be recorded as non-compliances along with the corrective actions taken and failure to do this is considered to render the fabrication to be in non-compliance with the Rules.

1.1.4 Welded constructions that comply with National or International specifications may be accepted to the satisfaction of the surveyor, provided that these specifications give reasonable equivalence to the requirements of this Chapter.

1.1.5 All welded construction is to be to the satisfaction of the Surveyor.

1.2 Design

1.2.1 Prior to commencing any work, the component to be manufactured is to be subjected to design review and approval in accordance with the Rule requirements.

1.2.2 The material characteristics that are affected by welding, particularly the loss of strength (e.g., in precipitation or strain hardened aluminium alloys) are to be considered in the design. The weld joints in such materials are to be arranged such that they are in areas of lower stress.

1.3 Materials

1.3.1 Materials used in welded construction are to be manufactured at works approved by LR. The use of materials from alternative sources will be subject to agreement of the Surveyor and satisfactory verification testing.

1.3.2 Materials are to be supplied and certified in accordance with the requirements of Chapters 1 to 10 of these Rules.

1.3.3 Materials used in welded construction are to be readily weldable and are to have proven weldability, unless requirements are agreed with LR in advance.

1.3.4 Where the construction details are such that materials are subject to through-thickness strains, consideration is to be given to using material with specified through-thickness properties as specified in Ch 3,8.

1.3.5 When ordering materials for construction, consideration is to be taken of the possible degradation of properties during fabrication or post-weld heat treatment. Where these materials are used, consideration is to be given to additional test requirements being specified to the supplier.

1.3.6 The identity of materials is to be established by way of markings etc, during fabrication, so that traceability to the original manufacturer's certificate is maintained.

1.3.7 Pre-fabrication shop primers may be applied prior to welding, provided that they are of an approved type and have been tested to demonstrate that they have no deleterious effects on the completed weld.

1.3.8 Where it is proposed to weld forgings and/or castings, full details of the joint details, welding procedures and post-weld heat treatments are to be submitted for consideration.

1.4 Requirements for manufacture and workmanship

1.4.1 The welding workshops are to be assessed by the Surveyor for their capability to produce work of the required quality in accordance with the requirements specified for the type of construction, *see* Sections 2 to 5.

1.4.2 Where structural components are to be assembled and welded in works sub-contracted by the builder, the Surveyor is to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter is achieved.

1.4.3 The manufacturer is to provide a system of regular supervision of all welding, by suitably qualified and experienced personnel.

1.4.4 Welding is to be performed in covered workshops as far as practicable. Where this is not possible, provision is to be made in the welding area to give adequate protection from wind, rain and cold, etc.

1.4.5 Where required, arrangements are to be such as to permit adequate ventilation and access for preheating, and for the satisfactory completion of all welding operations.

1.4.6 The location of welding connections and sequences of welding are to be arranged to minimise distortion and the build up of residual stresses. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

1.4.7 In the case of repairs to existing structures or components, care is to be exercised when attaching fit-up aids by welding to ensure that the base materials in way of the attachments are of weldable quality.

1.4.8 In order to prevent cross-contamination of different material types, the welding of carbon steel materials is to be in areas segregated from that used for either austenitic or non-ferrous materials, *see* Section 7.

1.5 Cutting of materials

1.5.1 Materials may be cut to the required dimensions by thermal means, shearing or machining in accordance with the manufacturing drawings or specifications.

1.5.2 Cold shearing is not to be used on materials in excess of 25 mm thick. Where used, the cut edges that are to remain un-welded are to be cut back by machining or grinding for a minimum distance of 3 mm.

1.5.3 Material, which has been thermally cut, is to be free from excessive oxides, scale and notches.

1.5.4 All cut edges are to be examined to ensure freedom from material and/or cutting defects. Visual examination may be supplemented by other techniques.

1.5.5 Thermal cutting of alloy and high carbon steels may require the application of preheat, and special examination of these cut edges will be required to ensure no cracking. In these cases, the cut edge is to be machined or ground back a distance of at least 2 mm, unless it has been demonstrated that the cutting process has not damaged the material.

1.5.6 Any material damaged in the process of cutting is to be removed by machining, grinding or chipping back to sound metal. Weld repair may only be performed with the agreement of the Surveyor.

1.6 Forming and bending

1.6.1 Plates, pipes, etc., may be formed to the required shape by any process which does not impair the quality of the material.

1.6.2 Where hot forming is employed or during cold forming where the material is subjected to a permanent strain exceeding 10 per cent or formed to a diameter to thickness ratio less than 10, tests are required to be performed to demonstrate that the material properties remain acceptable.

1.6.3 As far as practicable, forming is to be performed by the application of steady continuous loading using a machine designed for that purpose. The use of hammering, in either the hot or cold condition is not to be employed.

1.6.4 Material may be welded prior to forming or bending, provided that it can be demonstrated that the weld mechanical properties are not impaired by the forming operation. All welds subjected to bending are to be inspected on completion to ensure freedom from surface breaking defects.

1.7 Assembly and preparation for welding

1.7.1 Excessive force is not to be used in fairing and closing the work. Where excessive root gaps exist between surfaces or edges to be joined, corrective measures are to be adopted.

1.7.2 Provision is to be made for retaining correct alignment during welding operations in accordance with the approved manufacturing specifications and welding procedures.

1.7.3 Tack welds are to be avoided as far as practicable. When used, tack welds are to be of the same quality as the finished welds, made in accordance with approved welding procedures, and where they are to be retained as part of the finished weld, they are to be clean and free from defects.

1.7.4 Generally, tack welds are not to be applied in lengths of less than 30 mm for mild steel grades and aluminium alloys, and 50 mm for higher tensile steel grades. Smaller tack welds may be accepted for steels, provided that the carbon equivalent of the materials being welded is not greater than 0,36 per cent.

1.7.5 Where deep penetration welding is used (*see* 2.4.6), welding procedure tests are to demonstrate that the specified degree of penetration is achieved in way of tack welds left in place.

1.7.6 Where temporary bridge pieces or strong-backs are used, they are to be of similar materials to the base materials and welded in accordance with approved welding procedures.

1.7.7 Any fit-up aids and tack welds, where welded to clad materials, are to be attached to the base material and not to the cladding.

1.7.8 Surfaces of all parts to be welded, are to be clean, dry and free from rust, grease, debris and other forms of contamination.

1.7.9 When misalignment of structural members either side of bulkheads, decks etc., exceeds the agreed tolerance, the misaligned item is to be released, realigned and re-welded in accordance with an approved procedure.

1.8 Welding equipment and welding consumables

1.8.1 Welding plant and equipment is to be suitable for the purpose intended and properly maintained, taking into account relevant safety precautions.

1.8.2 Suitable means of measuring the welding parameters (i.e. current, voltage and travel speed) are to be available. Electrical meters are to be properly maintained and have current calibrations.

1.8.3 Welding consumables are to be suitable for the type of joint and grade of material to be welded, and in general, are to be LR Approved in accordance with Chapter 11.

1.8.4 Special care is to be taken in the distribution, storage and handling of all welding consumables. They are to be kept in heated dry storage areas with a relatively uniform temperature in accordance with the consumable manufacturer's recommendations. Condensation on the metal surface (e.g., wire electrodes and studs) during storage and use is to be avoided.

1.8.5 Prior to use, welding consumables are to be dried and/or baked in accordance with the consumable manufacturer's recommendations.

1.8.6 Satisfactory storage and handling facilities for consumables are to be provided close to working areas and the condition of welding consumables are to be subject to regular inspections.

1.9 Welding procedure and welder qualifications

1.9.1 Welding procedures are to be developed by the manufacturer for all welding, include weld repairs, and are to be capable of achieving the mechanical property requirements and non-destructive examination quality appropriate to the work being undertaken.

1.9.2 Welding procedures are to be established for the welding of all joints and are to be qualified by testing in accordance with Chapter 12. The welding procedures are to give details of the welding process, type of consumable, joint preparation, welding position and filler metals to be used.

1.9.3 The proposed welding procedures are to be approved by the Surveyor prior to construction.

1.9.4 All welders and welding operators are to be qualified in accordance with the requirements of Chapter 12. Qualification records to demonstrate that welding personnel have the skills to achieve the required standard of workmanship are to be available to the Surveyor.

1.10 Welding during construction

1.10.1 Materials to be assembled for welding are to be retained in position by suitable means such that the root gaps and alignment are in accordance with the approved manufacturing specifications and welding procedures.

1.10.2 Surfaces of all parts to be welded, are to be clean, dry and reasonably free from rust, scale and grease.

1.10.3 Pre-heat is to be applied, as specified in the approved welding procedure, for a distance of at least 75 mm from the joint preparation edges. The method of application and temperature control are to be such as to maintain the required level throughout the welding operation.

1.10.4 When the ambient temperature is 0°C or less, or where moisture resides on the surfaces to be welded, due care is to be taken to pre-heat the joint to a minimum of 20°C, unless a higher pre-heat temperature is specified.

1.10.5 Where tack welds are to be removed from the root of the weld joint, this is to be carried out such that the surrounding material and joint preparation is not damaged.

1.10.6 The welding arc is to be struck on the parent metal which forms part of the weld joint or on previously deposited weld metal.

1.10.7 Where the welding process used is slag forming (e.g., manual metal arc, submerged arc, etc.) each run of deposit is to be cleaned and free from slag before the next run is applied.

1.10.8 Full penetration welds are to be made from both sides of the joint as far as practicable. Prior to welding the second side, the weld root is to be cleaned, in accordance with the requirements of the approved welding procedure, to ensure freedom from defects. When air-arc gouging is used, care is to be taken to ensure that the ensuing groove is slag and oxide free and has a profile suitable for welding.

1.10.9 Where welding from one side only, care is to be exercised to ensure the root gap is in accordance with the approved welding procedure and the root is properly fused.

1.10.10 Particular care is to be exercised in welding in the vertical position with direction of travel downward (Vd) to avoid welding defects. The use of solid wire gas metal arc (GMAW) process in the vertical down position is to be avoided.

1.10.11 Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption.

1.10.12 After welding has been stopped for any reason, care is to be taken in restarting to ensure that the previously deposited weld metal is thoroughly cleaned of slag and debris, and preheat has been re-established.

1.10.13 Care is to be taken to avoid stress concentrations such as sharp corners or abrupt changes of section, and completed welds are to have an even contour, blending smoothly with the base materials. The weld shape and size is to be in accordance with that specified in the approved drawings or specifications.

1.10.14 Welded temporary attachments used to aid construction are to be removed carefully by grinding, cutting or chipping. The surface of the material is to be finished smooth by grinding followed by crack detection.

1.10.15 Where fabricated and welded components require to be machined, all major welding operations are to be completed prior to final machining.

1.10.16 Welding to parts which are subjected to rotating fatigue (e.g., shafts) is not generally permitted.

1.10.17 Welding onto parts that have been hardened for wear resistance or strength (e.g., gear teeth) is not permitted.

1.10.18 Where welding of clad ferritic steel plates is to be undertaken, the clad materials are to be ground back from the prepared edge by at least 10 mm. In general, the ferritic materials are to be welded prior to welding of the cladding material.

1.11 Non-destructive examination of welds

1.11.1 Non-destructive examinations are to be made in accordance with a definitive written procedure prepared and endorsed by a person qualified according to a Nationally Recognised Scheme with a grade equivalent to Level III qualification of ISO 9712, SNT-TC-1A, EN473, or ASNT Central Certification Program (ACCP). As a minimum, the procedure will identify personnel qualification levels, NDE datum and identification system, extent of testing, methods to be applied with technique sheets, acceptance criteria and reporting requirements. These procedures are to be reviewed by the Surveyor. *See* Ch 1,5.

1.11.2 Non-destructive examinations are to be undertaken by personnel qualified according to a Nationally Recognised Scheme with a grade equivalent to Level II qualification of ISO 9712, SNT-TC-1A, EN473 or ASNT Central Certification Program (ACCP). Operators qualified to Level I of the above schemes (or equivalent recognised by LR) may be engaged in testing under the supervision of personnel qualified to Level II or III (or equivalent recognised by LR). Personnel qualifications are to be verified by certification.

1.11.3 Effective arrangements are to be provided by the manufacturer for the inspection of finished welds to ensure that all welding, and where necessary, all post-weld heat treatment, has been satisfactorily completed.

1.11.4 Welds are to be clean and free from paint at the time of visual inspection unless specified otherwise in the following Sections.

1.11.5 The weld surface finish is to ensure accurate and reliable detection of defects. Where the weld surface is irregular or has other features likely to interfere with the interpretation of non-destructive examination, the weld is to be ground or machined.

1.11.6 Prior to inspection, welded temporary attachments and lifting eyes used to aid construction are to be removed carefully by grinding, cutting or chipping or other approved means. The surface of the material is to be finished smooth by grinding followed by crack detection. Any defects caused in the removal process are to be repaired and re-inspected.

1.11.7 For welds in steels with specified yield strength up to 400 N/mm^2, and with carbon equivalent less than or equal to 0,41 per cent, NDE may be performed as soon as the test assembly has cooled to ambient temperature. For other steels, NDE is to be delayed for a period of at least 48 hours after the test assembly has cooled to ambient temperature.

1.11.8 Non-destructive examinations are to be performed in accordance with the requirements of the Rules. Examinations are to be in accordance with agreed written procedures prepared by the manufacturer or ship builder.

1.11.9 The Surveyor may request additional inspections where there is reason to question the quality of workmanship, or where the weld is part of a complicated fabrication where there is high restraint or high residual stresses.

1.11.10 Welds are to be examined after completion of any post-weld heat treatment.

1.11.11 Where weld defects are discovered, the full extent is to be ascertained by applying additional non-destructive examinations where required. Unacceptable defects are to be completely removed and, where necessary, weld repaired in accordance with the relevant Sections of this Chapter. The repairs are to be re-inspected using the same technique as the original inspection.

1.11.12 Results of non-destructive examinations are to be recorded and evaluated by the constructor on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

1.11.13 The constructor is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance or otherwise with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

1.11.14 The extent of applied non-destructive examination is to be increased when warranted by the analysis of previous results.

1.12 Routine weld tests

1.12.1 Routine or production weld tests may be specified as a means of monitoring the quality of the welded joints. This type of quality control test is generally specified for pressure vessel and LNG construction but may be used for other types of welded fabrication.

1.12.2 Routine weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

1.12.3 Where routine test welds have been agreed, they are to be performed in accordance with the general requirements for the type of construction, *see* Sections 3 and 4.

1.13 Rectification of material defects

1.13.1 Repair of defects found in base materials is not to be carried out without the prior approval of the Surveyor.

1.13.2 In general, surface defects in the material may be removed by grinding, chipping, etc., provided the remaining material thickness is not reduced below the minimum thickness tolerance, and the area is ground to blend in smoothly with the surrounding material.

1.13.3 Confirmation that the defect has been removed is required by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.13.4 Surface defects, which cannot be repaired by the above method, may be repaired by welding where permitted by Chapters 3 to 9. Such repairs are to be performed in accordance with the requirements of this Section and those specified in Chapters 3 to 9.

1.13.5 Any defects in the structure resulting from the removal of temporary attachments are to be prepared, efficiently welded and ground smooth so as to achieve a defect free repair.

1.14 Rectification of distortion

1.14.1 Fairing, by linear or spot heating, to correct distortions due to welding, may be carried out. In order to ensure that the properties of the material are not adversely affected, approved procedures are to be utilised. On completion of such processes, visual examination of all heat affected areas in the vicinity is to be carried out to ensure freedom from cracking.

1.14.2 When misalignment of members exceeds the agreed tolerance, the misaligned item is to be cut apart, realigned and re-welded in accordance with an approved procedure.

1.15 Rectification of welds defects

1.15.1 Where repairs are extensive the manufacturer is to investigate the reason for the defects and take the necessary actions to prevent recurrence. In addition, consideration is to be given to the sequence of repairs and to providing temporary supports to prevent misalignment or collapse.

1.15.2 Cracks are to be reported to the Surveyor and the cause established prior to undertaking weld repairs.

1.15.3 Defects may be removed by grinding, chipping or thermal gouging. Where thermal gouging is used, the repair groove is to be subsequently ground clean to remove oxides and debris. The groove is to have a profile suitable for welding.

1.15.4 Prior to commencing repair welding, it is to be confirmed that no defect exists on the prepared surface by performing visual examination, augmented by either magnetic particle or dye penetrant examination techniques.

1.15.5 Repair welding is to be performed using approved welding procedures.

1.15.6 Completed repairs are to be re-examined by the non-destructive examination method(s) that detected the original defect and are to confirm that the original defect has been removed.

1.15.7 Where the component or structure has been subjected to post-weld heat treatment prior to weld repair, this is to be repeated after completion of all repair welding.

1.15.8 Where non-destructive examination reveals that the original defect has not been successfully removed, one more repair attempt may be performed.

1.15.9 The manufacturer is to monitor the quality of welding and maintain records of welding repairs and take the necessary corrective actions where repair rates are outside normal limits.

1.16 Post-weld heat treatment

1.16.1 On completion of welding, post-weld heat treatment may be required depending on the type of welded construction, the material type and thickness as specified by the relevant Parts or Sections of the Rules.

1.16.2 In general, heat treatment after welding is to be a stress relief treatment in order to reduce residual stresses introduced by welding and is generally applicable to ferritic steels. Where other types of heat treatment (e.g., normalising, solution annealing) are proposed, demonstration of acceptable mechanical properties of the weldment are to be confirmed by a welding procedure test which includes a simulated heat treatment.

1.16.3 Parts are to be properly prepared for heat treatment. Machined surfaces (e.g., flange faces, screw threads, etc.) are to be protected against scaling and sufficient temporary supports provided to prevent distortion or collapse of the structure.

1.16.4 Details of the heat treatment to be applied, soaking time and temperature, heating and cooling rates, etc., are to be submitted for review prior to commencing.

1.16.5 Post-weld heat treatment is to be carried out in a purpose built furnace which is efficiently maintained. In special cases, where the configuration of the component is such that thermal stresses during heating and cooling can be minimised, local post-weld heat treatment may be used. This would not normally apply to the complex geometry of cast materials during manufacture within the foundry environment.

1.16.6 In all cases, the heat treatment facilities and arrangements are to be capable of controlling the temperature throughout the heat treatment cycle and adequate means of measuring and recording the component temperature are to be provided. Thermocouples are to be attached so they are in contact with the component.

1.16.7 Unless specified otherwise, stress relief heat treatment is to be carried out by means of controlled heating from 300°C, to the soak temperature, holding within the prescribed soaking temperature range for the time specified (usually 1 hour per 25 mm of weld thickness) followed by controlled cooling to below 300°C.

1.16.8 Where post-weld stress relief is specified for welded constructions that contain joints between different materials (e.g. ferritic to austenitic steels), the details of the materials, welding procedures and heat treatment cycle to be applied are to be submitted for special consideration and approval.

1.16.9 Non-destructive examination of welds is to be performed after completion of any heat treatment.

1.17 Certification

1.17.1 Products or components are not to be considered complete until all the requirements of the construction specification have been met and all activities have been completed.

1.17.2 Upon completion of the works, the manufacturer is to provide documentation which indicates that:

(a) All welds are complete and there are no outstanding repairs.
(b) The appropriate post-weld heat treatments have been performed.
(c) Appropriate destructive tests have been performed.
(d) Proof testing of welds has been performed.

1.17.3 Before the test certificates or shipping statements are signed by the Surveyor, the manufacturer is required to provide a written declaration stating that the product is in accordance with the requirements of 1.17.2.

■ *Section 2* Specific requirements for ship hull structure and machinery

2.1 Scope

2.1.1 The requirements of this Section apply to the construction of ships, including hull structure, superstructure and deckhouses, components forming part of the ship structure and its machinery (excluding pressure equipment and piping, *see* Section 4). These requirements are in addition to the general welding requirements specified in Section 1.

2.1.2 The shipyard and manufacturer's works are to be assessed to give assurance that they have the facilities, equipment, personnel and quality control procedures to produce work of the required quality.

2.2 Welding consumables

2.2.1 Welding consumables used for hull construction are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of material to be welded.

2.2.2 Steel welding consumable approvals, up to and including Grade Y40 and Y47, are considered acceptable for hull construction in line with Table 11.1.1 in Chapter 11, Ch 12,2.2.2 and the following:

(a) Consumables up to Grade Y are acceptable for welding steels up to 3 strength levels below that for which the approval applies, e.g., a consumable with approval grading 3Y is acceptable for welding EH36, EH32 and EH27S higher tensile ship steels and grade E normal strength ship steel.
(b) Consumables for Grade Y40 are acceptable for welding steels up to two strength levels below that for which the approval applies. Consumables for Grade Y47 are acceptable for welding steels up to one strength level below that for which the approval applies.
(c) Consumables with an approved impact toughness grading are acceptable for welding steels with lower specified impact properties subject to (a) above, e.g. a consumable with approval grading 3Y is acceptable for welding EH, DH and AH materials.
(d) For welding steels of different grades or different strength levels, the welding consumables may be of a type suitable for the lesser grade or strength being connected. The use of a higher grade of welding consumable may be required at discontinuities or other points of stress concentration.

2.2.3 In general, the use of preheating and hydrogen controlled welding consumables for welding of ship steels up to strength grade H40 is to be in accordance with Table 13.2.1. The carbon equivalent is to be calculated from the ladle analysis using the formula given below:

$$\text{Carbon equivalent} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{NI + Cu}{15}$$

Preheat and the use of low hydrogen controlled consumables will be required for welding of steel grades higher than Grade H40.

Table 13.2.1 Preheat and consumable requirements for welding of carbon and carbon manganese steels up to strength grade H40

Carbon equivalent C_{eq}	Pre-heat	Hydrogen controlled consumables
C_{eq} equal to or less than 0,41%	Not required	Not required, *see* Note 3
C_{eq} above 0,41 but not exceeding 0,45%	Not required, *see* Notes 1 and 2	Required
C_{eq} greater than 0,45%	Required	Required

NOTES
1. Preheat may need to be applied in order to meet the maximum hardness values specified in Ch 12,2.12.6.
2. Under conditions of high restraint or low ambient temperature preheat may need to be applied.
3. Hydrogen controlled consumables may need to be considered for welding of
   (a) Thicker materials (i.e., > 35 mm).
   (b) Higher strength materials.
   (c) Welds subject to high restraint.

2.2.4 All aluminium alloy welding consumables are to be approved in accordance with Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.2.

Table 13.2.2 Welding of aluminium alloys – Consumable requirements

Consumable approval grade	Base material alloy grade
RA or WA	5754
RB or WB	5086, 5754
RC or WC	5083, 5086, 5754
RD or WD	6005A, 6061, 6082

2.2.5 All austenitic stainless steel and duplex stainless steel welding consumables are to be approved in accordance with the Chapter 11 and are suitable for welding the grades of material as shown in Table 13.2.3.

2.3 Welding procedure and welder qualifications

2.3.1 Welding procedures and welder qualifications are to be tested and approved in accordance with the requirements of Chapter 12.

2.4 Construction and workmanship

2.4.1 Weld preparations and openings may be formed by thermal cutting, machining or chipping. Chipped surfaces that will not be subsequently covered by weld metal are to be ground smooth.

Table 13.2.3 Welding of austenitic stainless and duplex stainless steels – Consumable requirements

Consumable approval grade	Suitable for welding material alloy grades
Austenitic stainless steels	
321	321
347	347 and 321
Austenitic stainless steel – Low carbon	
304L (*see* Note 3)	304L
304LN (*see* Note 3)	304LN and 304L
316L	316L and 304L
316LN	316LN, 316L, 304LN and 304L
317L	317L, 316LN, 316L, 304LN and 304L
317LN	317LN, 317L, 316LN, 316L, 304LN and 304L
Super austenitic stainless steels, *see* Note 2	
S31254	S31254 and N08904
N08904	N08904
Duplex stainless steels, *see* Note 1	
S31260	S31260 and S31803
S31803	S31803
S32550	S32550
S32750	S32750 and S32550
S32760	S32760, S32550, S31260 and S31803
Stainless steels welded to carbon steels	
SS/CMn	Carbon steel to all steels in Sections 1, 2 and 3
Duplex/CMn	Carbon steel to all duplex stainless steel in Section 4

NOTES
1. The use of a different welding consumable grade from that of the base material may require demonstration of acceptable corrosion properties.
2. May be used for welding low carbon austenitic grades provided measures are taken to prevent solidification cracking from occurring.
3. These are LR Grades and do not correspond to any National or International Standards/Grades.

2.4.2 Prior to welding, the alignment of plates and stiffeners forming part of the hull structure is to be in accordance with the tolerances specified in the relevant part of the Rules.

2.4.3 When welding from one side only, care is to be exercised to ensure the root gap and fit up are in accordance with the approved welding procedure and the root is properly fused.

2.4.4 Where it is proposed to use permanent backing strips, the intended locations and welding procedures are to be submitted for consideration.

2.4.5 Temporary backing strips may be used provided they are in accordance with approved welding procedures and are subsequently removed on completion of welding.

2.4.6 The outer surfaces of completed welds are to blend smoothly with the base materials and provide a smooth transition and gradual change of section.

2.4.7 Weld joints in parts of oil engine structures that are stressed by the main gas or inertia loads are to be designed as continuous full penetration welds. They are to be arranged so that welds do not intersect, and that welding can be effected without difficulty.

2.4.8 When modifications or repairs have been made which result in openings having to be closed by welded inserts, particular care is to be given to the fit of the insert and the welding sequence. The welding is also to be subject to non-destructive examination.

2.4.9 Where welding of aluminium alloy is employed, the following additional requirements are to be complied with so far as they are applicable:

(a) Welding is to be performed by fusion welding using inert gas or tungsten inert gas process or by the friction stir welding process. Where it is proposed to use other welding processes, details are to be submitted for approval.

(b) The weld joint surfaces should be scratch brushed, preferably immediately before welding, in order to remove oxide or adhering films of dirt, filings, etc.

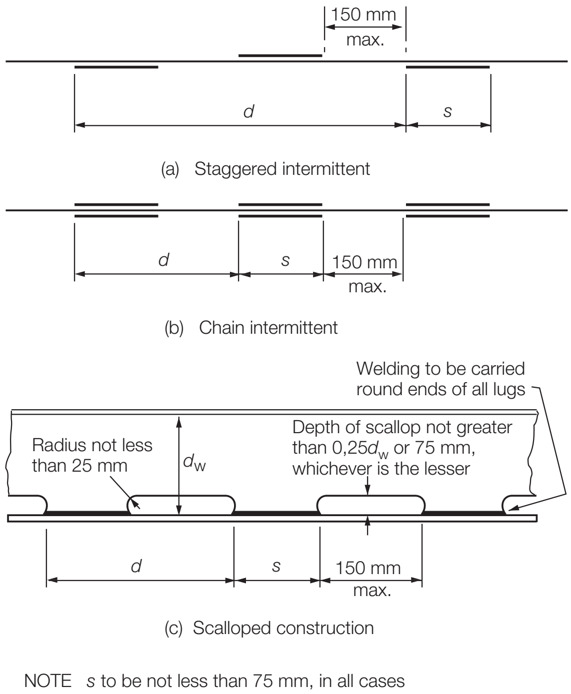


Fig. 13.2.1 Weld types

2.5 Butt welds

2.5.1 Where the ship hull is constructed of plates of different thicknesses, the thicker plates are to be chamfered in accordance with the approved plans. In all cases the chamfer is not to exceed a slope of 1 in 3 so that the plates are of equal thickness at the weld seam. Alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate provided the difference in thickness is not greater than 3 mm.

2.5.2 Where stiffening members are attached by continuous fillet welds and cross completely finished butt or seam welds, these are to be made flush in way of the fillet weld. Similarly for butt welds in webs of stiffening members, the butt weld is to be complete and generally made flush with the stiffening member before the fillet weld is made. Where these conditions cannot be complied with, a scallop is to be arranged in the web of the stiffening member, *see* Fig. 13.2.1. Scallops are to be of such a size and in such a position that a satisfactory weld can be made.

2.6 Lap connections

2.6.1 Overlaps are generally not to be used to connect plates which may be subjected to high tensile or compressive loading and alternative arrangements are to be considered. However, where plate overlaps are adopted, the width of the overlap is not to exceed four times, nor be less than three times the thickness of the thinner plate and the joints are to be positioned to allow adequate access for completion of sound welds. The faying surfaces of lap joints are to be in close contact and both edges of the overlap are to have continuous fillet welds.

2.7 Closing plates

2.7.1 For the connection of plating to internal webs, where access for welding is not practicable, the closing plating is to be attached by continuous full penetration welds or by slot fillet welds to face plates fitted to the webs. Slots are to have a minimum length of 90 mm and a minimum width of twice the plating thickness, with well rounded ends. Slots cut in plating are to be smooth and clean and are to be spaced not more than 230 mm apart, centre to centre. Slots are not to be filled with welding.

2.7.2 For the attachment of rudder shell plating to the internal stiffening of the rudder, slots are to have a minimum length of 75 mm and, in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded and the space between them is not to exceed 150 mm.

2.8 Stud welding

2.8.1 Where permanent or temporary studs are to be attached by welding to main structural parts in areas subject to high stress, the proposed location of the studs and the welding procedures adopted are to be approved.

2.9 Fillet welds

2.9.1 T-connections are generally to be made by fillet welds on both sides of the abutting plate, the dimensions and spacing of which are shown in Fig. 13.2.1. Where the connection is highly stressed, deep penetration or full penetration welding may be required. Where full penetration welding is required, the abutting plate may be required to be bevelled.

2.9.2 Where an approved deep penetration procedure is used, the fillet leg length calculated may be reduced by 15 per cent provided that the manufacturer is able to meet the following requirements:

(a) Use of a welding consumable approved for deep penetration welding in accordance with Chapter 11 for either the 'p' or 'T' techniques.
(b) Demonstrations by way of production weld testing that the minimum required penetration depths (i.e., throat thicknesses) are maintained. This is to be documented on a monthly basis by the manufacturer and be available to the Surveyor.

2.9.3 The calculated fillet leg length may be reduced by 20 per cent, provided that in addition to the requirements of 2.9.2(a) and (b), the manufacturer is able to consistently meet the following additional requirements:

(a) The documentation required in 2.9.2(b) is to be completed and made available to the Surveyor upon request on a weekly basis.
(b) Suitable process selection confirmed by satisfactory welding procedure tests covering both minimum and maximum root gaps.

2.9.4 Where intermittent welding is used, the welding is to be made continuous in way of brackets, lugs and scallops and at orthogonal connections with other members.

2.10 Post-weld heat treatment

2.10.1 Post-weld stress relief heat treatment is applied to improve the fatigue performance or to improve resistance to brittle fracture and is generally required for carbon and carbon-manganese and low alloy steels under any of the following conditions:

(a) Where the material thickness exceeds 65 mm.
(b) For complicated weld joints where there are high stress concentrations.
(c) Where fatigue loads are considered high.

2.10.2 Post-weld heat treatment is to be applied to the following types of welded construction:

(a) Welding of steel castings where the thickness of the casting at the weld exceeds 30 mm, except where castings are directly welded to the hull structure.
(b) Oil engine bedplates except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need to be stress relieved.
(c) Welding of gear wheels.
(d) Welding of gear cases associated with main or auxiliary engines, *see* Part 5 of the Rules for Ships.

2.10.3 Where required, heat treatment is to be performed in accordance with the requirements specified in 4.6 for pressure vessel construction.

2.10.4 Special consideration may be given to omit the required post-weld heat treatment. Evaluation is to be based on critical engineering assessment involving fracture mechanics testing and proposals are to be submitted which include full details of the application, materials, welding procedures, inspection procedures, design stresses, fatigue loads and cycles. Evidence will be required to demonstrate that the inspection techniques and procedures to be employed are able to detect flaws down to the sizes determined from the fracture mechanics (and or fatigue) calculations.

2.11 Tolerances

2.11.1 Tolerances after welding are to be in accordance with the relevant Part of the Rules.

2.11.2 Distortion which has resulted from welding may be corrected by spot heating in accordance with 1.14.

2.12 Non-destructive examination of welds

2.12.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and slag. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and under-fill of welds is avoided.

2.12.2 Welds forming part of the hull and superstructure may be coated with a thin layer of protective primer prior to inspection provided it does not interfere with inspection and is removed, if required by the Surveyor, for closer interpretation of possible defective areas.

2.12.3 All welds are to be visually inspected by personnel designated by the builder. Visual inspection of all welds may be supplemented by other non-destructive examination techniques in cases of unclear interpretation, as considered necessary. The acceptance criteria for visual testing are given in Table 13.2.4.

2.12.4 In addition to visual inspection, welded joints are to be examined using any one or a combination of ultrasonic, radiographic, magnetic particle, eddy current, dye penetrant or other acceptable methods appropriate to the configuration of the weld.

Table 13.2.4 Acceptance criteria for visual testing, magnetic particle and liquid penetrant testing

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria for visual testing
Crack	100	Not accepted
Lack of fusion	401	Not accepted
Incomplete root penetration in butt joints welded from one side	4021	Not accepted
Surface pore	2017	Single pore diameter $d \leq 0{,}25t$, for butt welds, with maximum diameter 3 mm, *see* Note 1 $d \leq 0{,}25a$, for fillet welds, with maximum diameter 3 mm, *see* Note 1 2,5d as minimum distance to adjacent pore
Undercut in butt welds	501	Depth ≤ 0,5 mm, whatever the length Depth ≤ 0,8 mm, with a maximum continuous length of 90 mm, *see* Note 2
Undercut in fillet welds	501	Depth ≤ 0,8 mm, whatever the length

NOTES
1. t is the plate thickness of the thinnest plate, and a is the throat of the fillet weld.
2. Adjacent undercuts separated by a distance shorter than the shortest undercut are to be regarded as a single continuous undercut.

2.12.5 The method to be used for the volumetric examinations of welds is the responsibility of the builder. Radiography is generally preferred for the examination of butt welds of 8 mm thickness or less. Ultrasonic testing is acceptable for welds of 8 mm thickness or greater and is to be used for the examination of full penetration tee butt or cruciform welds or joints of similar configuration. Advanced ultrasonic techniques, such as Phased Array Ultrasonic Testing (PAUT), may be used as a volumetric testing method in lieu of radiography or manual ultrasonic testing. If these methods are used, the thickness limitations for manual ultrasonic testing apply.

2.12.6 The acceptance criteria for radiographic testing are given in Table 13.2.5, and those for ultrasonic testing in Table 13.2.6.

2.12.7 Checkpoints examined at the pre-assembly stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspection of weld ends.

2.12.8 Checkpoints examined at the assembly stage are generally to be selected from those welds intended to be examined as part of the agreed quality control programme to be applied by the builder. The locations and number of checkpoints are to be approved by the Surveyor.

2.12.9 Where components of the structure are subcontracted for fabrication, the same inspection regime is to be applied as if the item had been constructed within the main contractor's works. In these cases, particular attention is to be given to highly loaded fabrications (such as stabiliser fin boxes) forming an integral part of the hull envelope.

2.12.10 Particular attention is to be paid to highly stressed items. Magnetic particle inspection is to be used at ends of fillet welds, T-joints, joints or crossings in main structural members and at stern frame connections.

2.12.11 Special attention is to be given to the examination of plating in way of lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed, but includes the positions where lifting eye plates are permanent fixtures.

2.12.12 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

2.12.13 Typical locations for volumetric examination and number of checkpoints to be taken are given in the relevant Sections of the Rules. A list of the proposed items to be examined is to be submitted for approval.

2.12.14 For the hull structure of refrigerated spaces, and of ships designed to operate in low air temperatures, the extent of non-destructive examination will be specially considered. For non-destructive examination of gas ships *see* the *Rules for the carriage for Liquefied Gases*.

2.12.15 For all ship types, the builder is to carry out random non-destructive examination at the request of the Surveyor.

2.12.16 Results of non-destructive examinations made during construction are to be recorded and evaluated by the builder on a continual basis in order that the quality of welding can be monitored. These records are to be available to the Surveyor.

2.12.17 The extent of applied non-destructive examinations is to be increased when warranted by the analysis of previous results.

Table 13.2.5 Acceptance criteria for radiographic testing

Discontinuity	Classification according to ISO 6520-1	Acceptance criteria for radiographic testing, *see* Note 1
Crack	100	Not accepted
Lack of fusion	401	Continuous maximum length $t/2$ or 25 mm, whichever is the less, *see* Note 2 Intermittent cumulative length maximum t or 50 mm, whichever is less, *see* Note 3
Lack of root fusion	4013	Not accepted in butt joints welded from one side
Incomplete root penetration	4021	Not accepted in butt joints welded from one side
		Continuous maximum length $t/2$ or 25 mm, whichever is lesser, *see* Note 2 Intermittent cumulative maximum length t or 50 mm, whichever is less, *see* Note 3
Slag inclusion	301	Continuous maximum length t or 50 mm, whichever is less, *see* Note 2 Intermittent cumulative length maximum $2t$ or 100 mm, whichever is less, *see* Notes 3 and 4
Gas pore	2011	Maximum dimension for a single pore: $d \leq 0,2t$, max. 4,0 mm *see* Note 5
Uniformly distributed porosity	2012	Maximum dimension of the area of imperfections: For single run welds: ≤ 1,5% For multi-run welds: ≤ 3% *See* Notes 6 and 7
Clustered (localised) porosity	2013	Maximum dimension of the summation of the projected area of the imperfection: ≤ 8% *See* Notes 6 and 7
Elongated cavity	2015	$h \leq 0,3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Wormholes	2016	$h \leq 0,3t$, max. 3,0 mm $l \leq t$, max. 50 mm *See* Notes 8 and 9
Metallic inclusions other than copper	304	$h \leq 0,3t$, max. 3,0 mm *See* Note 8
Copper inclusions	3042	Not permitted

NOTES
1. t is the thickness of the thinnest plate.
2. Two adjacent individual discontinuities of length l_d1 and l_d2 situated on a line and where the distance l_d between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length $l_d1 + l_d + l_d2$.
3. Sum of the length of individual continuous discontinuities.
4. Parallel inclusions not separated by more than 3 times the width of the largest inclusion are to be regarded as one continuous discontinuity.
5. d is the diameter of the gas pore.
6. The limits for the maximum single gas pore within this group still apply.
7. Further reference to porosity limits may be obtained in ISO 5817:2007.
8. h is the width of the imperfection.
9. l is the length of the imperfection.

2.13 Weld repairs

2.13.1 The full extent of any weld defect is to be ascertained by applying additional non-destructive examination where required. Unacceptable defects are to be completely removed and, where necessary, re-welded and re-examined in accordance with the requirements of 1.15.

2.13.2 During the assembly of large components, root gaps in excess of those specified in the approved welding procedure may be rectified by welding.

Table 13.2.6 Acceptance criteria for ultrasonic testing

Echo height	Acceptance criteria for ultrasonic testing, *see* Note
Greater than 100% of DAC curve	Maximum length t/2 or 25 mm, whichever is less
Greater than 50% of DAC curve, but less than 100% of DAC curve	Maximum length t or 50 mm, whichever is less
Indications evaluated to be cracks are unacceptable regardless of echo height; Indications evaluated to be lack of penetration or lack of root fusion in joints welded from one side are unacceptable regardless of echo height.	
NOTE Two adjacent individual discontinuities of length L1 and L2 situated on a line and where the distance L between them is shorter than the shortest discontinuity are to be regarded as a continuous discontinuity of length L1 + L + L2.	

2.13.3 Rectification of wide root gaps in butt welds, up to a maximum gap of 16 mm, may be performed provided that the length of these areas is small in relation to the whole weld length. Repairs may be executed by applying weld buttering layers to one edge of the weld joint, followed by machining or grinding to return the root opening to the required dimensions. The weld buttering and filling of the joint are to be in accordance with welding procedures qualified in accordance with Chapter 12.

2.13.4 For sub-assemblies, rectification of wide root gaps may be performed using a backing strip, provided that it is removed on completion of the welding.

2.13.5 Rectification of wide root gaps in fillet welds may be carried out as follows:

(a) where the root gap, g, is in excess of 3 mm, but not greater than 5 mm, the fillet leg length, z, may be increased by g – 2,0 mm;
(b) where the root gap is in excess of 5 mm, the joint detail may be changed into a full penetration weld.

2.13.6 Where repair welds are made using small weld beads, suitable precautions (including preheat) are to be taken to avoid high hardness and possible cold cracking.

2.14 Welding afloat with water backing

2.14.1 Welding afloat with water backing is not recommended due to the additional precautions required during survey and therefore, is generally not permitted. However consideration may be given to welding afloat with water backing after specific LR approval has been obtained by the yard or fabricator prior to such welding being carried out. Such approval will only be given once all of the following conditions are satisfied:

(a) The welding procedure qualification tests are carried out on steel plates with water backing and the water is maintained at the flow rate and minimum water temperature anticipated during fabrication.
(b) The carbon equivalent of the steel plates used in the welding procedure qualification tests are to be greater than 0,41 per cent based on the IIW formula. Where it can be shown that all hull steel plates and new sections will have a carbon equivalent value below this figure, steel plates with the maximum carbon equivalent value may be used for the welding procedure qualification tests.
(c) Welding procedure qualification tests are carried out without preheat.
(d) The thickness of steel plate used in the welding procedure qualification test is the minimum hull plate thickness to be used during fabrication.
(e) The maximum measured hardness on the completed welding procedure qualification assembly is less than or equal to 350 HV10. Following fabrication welding, 10 per cent of welds are to be hardness tested in way of heat-affected zones at weld starts to confirm compliance with the 350 HV10 limit.
(f) The heat input used in the welding qualification test is the minimum permitted heat input during fabrication.
(g) Only low hydrogen welding consumables (H5) are used.
(h) In addition to normal non-destructive testing for welds, 10 per cent of the welds are additionally subject to magnetic particle inspection 48 hours after welding is complete.
(j) The welding procedure qualification tests for the repair of welds carried out afloat with water backing are to be carried out on test pieces that have previously been welded afloat and also meet the requirements above.

2.14.2 Welding in, or underwater, is not permitted.

■ *Section 3*
Specific requirements for fabricated steel sections

3.1 Scope

3.1.1 Fabricated steel sections are items used in place of rolled sections and as such will not be regarded as sub-assemblies. Products regarded as sub-assemblies are subject to requirements of welded construction specified in Section 2.

3.1.2 The requirements for structural steel sections are based on these being manufactured from flat products by automatic welding and intended for use in the construction of ships and other marine structures.

3.1.3 Fabricated steel sections are to be manufactured in accordance with the requirements of this Section and the general requirements of Section 1.

3.1.4 In all cases, sections are to be manufactured at works, which have been assessed and approved in accordance with *Materials and Qualification Procedures for Ships, Book J, MQPS Procedure 12-1*.

3.2 Dimensions and tolerances

3.2.1 Products are to conform dimensionally to the provisions of an acceptable National or International Standard.

3.2.2 The minimum throat thickness of fillet welds is to be determined from:

Throat thickness = $0,34t$ but not to be taken as less than 3 mm

where

t = plate thickness of the thinner member to be joined (generally the web).

3.2.3 Where a welding procedure using deep penetration welding is used (*see* Chapter 11, 'p' and 'T' welding techniques) the minimum leg length required will be specially considered provided the requirements of 2.9.2 are complied with.

3.2.4 Unless agreed otherwise, the leg length of the weld is to be not less than 1,4 times the specified throat thickness.

3.3 Identification of products

3.3.1 Every finished item is to be clearly marked by the manufacturer in at least one place with the following particulars:

(a) The manufacturer's name or trade mark.
(b) Identification mark for the grade of steel.
(c) Identification number and/or initials which will enable the full history of the item to be traced.
(d) Where required by the purchaser, the order number or other identification mark.
(e) The letters 'LR'.
(f) The Surveyor's personal stamp.

The above particulars, but excluding the manufacturer's name or trade mark where this is embossed on finished products, are to be encircled with paint or otherwise marked so as to be easily recognisable.

3.3.2 In the event of any material bearing LR's brand failing to comply with the test requirements, the brand is to be removed or unmistakably defaced, *see also* Ch 1,4.7.

3.4 Manufacture and workmanship

3.4.1 For cut edges that are to remain unwelded, it is to be demonstrated that the plate preparation procedures used are able to achieve edges that are free from cracks or other deleterious imperfections.

3.4.2 Where assembly jigs and devices are used to bring the web into contact with the flanges and hold these in place during welding, means are to be provided to ensure that the degree of contact is maintained until welding is complete.

3.4.3 Welding procedures are to be established for the welding of all joints including weld repairs and are to be approved in accordance with Chapter 12. Welders are to be approved in accordance with Chapter 12, and qualification records are to be available to the Surveyor.

3.4.4 The welding consumables used are to be approved in accordance with Chapter 11 and are to be suitable for the type of joint and grade of steel as described in 2.2. For joining steel of different tensile strengths, the consumables are to be suitable for the tensile strength of the component considered in the determination of weld size.

3.4.5 The application of pre-heat and the use of low hydrogen welding consumables are to be in accordance with the requirements of 2.2.

3.4.6 Welding is to be double continuous fillet welding or full penetration welding as specified in the approved plans.

3.4.7 Where deep penetration welding is used, the requirements of 2.9.2 are to be complied with.

3.5 Non-destructive examination

3.5.1 Surface inspection and verification of dimensions are the responsibility of the manufacturer and are to be carried out on all materials prior to despatch. Acceptance by the Surveyor of material later found to be defective does not absolve the manufacturer from this responsibility.

3.5.2 The Surveyor will carry out checks to ensure that the weld size and profile are in accordance with the manufacturing specification and the manufacturer's Quality Control Procedures.

3.5.3 The manufacturer is to examine the welds by magnetic particle or dye penetrant methods. The length examined is to be 200 mm at each end, for each length cut for delivery.

3.5.4 If cracks are revealed, these are to be reported to the Surveyor and the whole of the length is to be examined by magnetic particle or dye penetrant methods. Corrective action in respect of the manufacturing process, and repairs are to be as indicated in the manufacturers' Quality Control Manual.

3.5.5 The weld defect is not to exceed the acceptance levels given in Table 13.2.4.

3.6 Routine weld tests

3.6.1 One production batch test is required for every 500 m of fabricated section manufactured, or fraction thereof. From each batch test, two samples are to be removed, one from near the beginning of the production run and one from near the end. From each of these test samples one macro specimen and one fracture test specimen are to be taken.

3.6.2 The macro specimens are to be prepared and etched to demonstrate freedom from unacceptable defects and that the weld penetration is in accordance with the manufacturing specification. The fracture specimens are to be broken, one for each side of the fillet weld, and the fractured surfaces examined for compliance with the requirements of Table 13.2.5.

3.6.3 Where the welding procedure used has employed the deep penetration technique, the amount of root penetration is to be measured on the macro specimen and is not to be less than that demonstrated during welding procedure approval testing.

3.6.4 For the purposes of this Section, a batch is to consist of products of only one size and grade of material.

3.7 Certification and records

3.7.1 Each test certificate is to include the following particulars:

(a) Purchaser's name and order number.
(b) Where known, the contract number for which the material is intended.
(c) Address to which material is despatched.
(d) Description and dimensions of the product.
(e) Specification or grade of the steel.
(f) Identification number and/or initials.
(g) Cast number and chemical composition of ladle samples of constituent plates.
(h) Mechanical test results of constituent plates.
(j) Condition of supply when other than as-rolled.
(k) Make and brand of welding consumables.

3.7.2 Test certificates or shipping statements may be signed by the Surveyor, provided the documentation requirements of 1.17 are satisfied. The following form of declaration will be accepted if stamped or printed on each test certificate or shipping statement with the name of the works and signed by an authorised representative of the manufacturer:

'We hereby certify that the material has been made by an approved procedure in accordance with the Lloyd's Register's Rules for Materials'.

3.7.3 The manufacturer is to maintain records by which sources of material can be identified together with the results of all inspections and tests.

■ *Section 4*
Specific requirements for fusion welded pressure vessels

4.1 Scope

4.1.1 The requirements of this Section apply to fusion welded pressure vessels and process equipment, heating and steam raising boilers, and steam or gas turbine rotors and cylinders and are in addition to those requirements referred to in Section 1.

4.1.2 The allocation of pressure vessel Class is determined from the design criteria in Pt 5, Ch 10 and 11 of the Rules for Ships. Prior to commencing construction, the design of the vessel is to be approved. Construction requirements for turbine rotors and cylinders are to be in accordance with Class 2/1, unless a higher Class is specified in the approved plans.

4.1.3 Pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding work required for the Class of vessel proposed. The manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships, Book A, Procedure MQPS 0-4*.

4.1.4 The term 'fusion weld', for the purpose of these requirements, is applicable to welded joints made by manual, semi-automatic, or automatic electric arc welding processes. Special consideration will be given to the proposed use of other fusion welding processes.

4.2 Cutting and forming of shells and heads

4.2.1 Cut or chipped surfaces which will not be subsequently covered by weld metal are to be ground smooth.

4.2.2 Shell plates and heads are to be formed to the correct contour up to the extreme edge of the plate.

4.2.3 Vessels manufactured from carbon or carbon manganese steel plates (*see* Table 3.4.1 in Chapter 3, grades 360AR to 510FG), which have been hot formed or locally heated for forming, are to be re-heat treated in accordance with the original supplied condition on completion of this operation. Vessels formed from plates supplied in the as-rolled condition are to be heat treated in accordance with the material manufacturer's recommendations.

4.2.4 Subsequent heat treatment will not be required where steels are supplied in the as-rolled, normalised or normalised and controlled rolled condition, or hot forming is carried out entirely at a temperature within the normalising range.

4.2.5 For alloy steel vessels where hot forming is employed (*see* Table 3.4.1 in Chapter 3, 13Cr Mo 45, etc.), the plates are to be heat treated on completion in accordance with the material manufacturer's recommendations.

4.2.6 Where plates are cold formed, subsequent heat treatment is to be performed where the internal radius is less than 10 times the plate thickness. For carbon and carbon-manganese steels this heat treatment may be a stress relief heat treatment.

4.2.7 In all cases where hot forming is employed, and for cold forming to a radius less than 10 times the thickness, the manufacturer is required to demonstrate that the forming process and subsequent heat treatments result in acceptable properties.

4.3 Fitting of shell plates and attachments

4.3.1 The location of welded joints is to be such as to avoid intersecting butt welds in the vessel shell plates. The attachment of nozzles and openings in the vessels are to be arranged to avoid main shell weld seams.

4.3.2 The surfaces of the plates at the longitudinal or circumferential seams are not to be out of alignment with each other, at any point, by more than 10 per cent of the plate thickness. In no case is the misalignment to exceed 3 mm for longitudinal seams, or 4 mm for circumferential seams.

4.3.3 Where a vessel is constructed of plates of different thicknesses (tube plate and wrapper plate), the plates are to be so arranged that their centrelines form a continuous circle.

4.3.4 For longitudinal seams, the thicker plate is to be equally chamfered inside and outside by machining over a circumferential distance not less than twice the difference in thickness, so that the plates are of equal thickness at the longitudinal weld seam. For the circumferential seam, the thickest plate is to be similarly prepared over the same distance longitudinally.

4.3.5 For the circumferential seam, where the difference in the thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the weld joint. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper to the thicker plate.

4.3.6 All attachments (lugs, brackets, reinforcing plates, etc.) are to conform to the shape of the surface to which they are attached.

4.4 Welding

4.4.1 Welding procedures are to be established for all welds joining pressure containing parts and for welds made directly onto pressure containing parts. Welding procedures are to be based on qualification tests performed in accordance with Chapter 12.

4.4.2 In all cases where tack welds, in the root of the weld seam, are used to retain plates or parts in position prior to welding, they are to be removed in the process of welding the seam.

4.4.3 Steel backing strips may be used for the circumferential seams of Class 2/1, Class 2/2 and Class 3 pressure vessels and are to be the same nominal composition as the plates to be welded.

4.4.4 Fillet welds are to be made to ensure proper fusion and penetration at the root of the fillet. At least two layers of weld metal are to be deposited at each weld affixing branch pipes, flanges and seatings.

4.4.5 The outer surface of completed welds is to be at least flush with the surface of the plates joined, and any weld reinforcement is to provide a smooth transition and gradual change of section with the plate surface.

4.4.6 Where attachment of lugs, brackets, branches, manhole frames, reinforcement plates and other members are to be made to the main pressure shell by welding, this is to be to the same standard as required for the main vessel shell construction.

4.4.7 The main weld seams and all welded attachments made to pressure containing parts are to be completed prior to post weld heat treatment.

4.4.8 The finish of welds attaching pressure parts and non-pressure parts to the main pressure shell is to be such as to allow satisfactory examination of the welds. In the case of Class 1 and Class 2/1 pressure vessels, these welds are to be ground smooth, if necessary, to provide a suitable finish for examination.

4.5 General requirements for routine weld production tests

4.5.1 Routine weld production tests are specified as a means of monitoring the quality of the welded joints and are required for pressure vessel Classes 1, 2/1 and 2/2.

4.5.2 Routine production test plates are required during the manufacture of vessels and as part of the initial approval test programme for Class 1 vessel manufacturers, refer to MQPS 0-4.

4.5.3 Routine production weld tests are not required for Class 3 pressure vessels unless there are doubts about the weld quality where check tests may be requested by the Surveyor.

4.5.4 Routine production test plates are not required for circumferential seams of cylindrical pressure vessels. Spherical vessels are to have one test plate prepared having a welded joint which is a simulation of the circumferential seams.

4.5.5 Routine production weld tests may be requested by the Surveyor where there is reason to doubt the quality of workmanship.

4.6 Production test plate assembly requirements

4.6.1 Two test plates and one complete test assembly, of sufficient dimensions to provide all the required mechanical test specimens is to be prepared for each vessel and is to be welded as a continuation and simulation of the longitudinal weld joint.

4.6.2 For Class 2/2 vessels, where a large number are made concurrently at the same works using the same welding procedure and the plate thicknesses do not vary by more than 5 mm, one test may be performed for each 37 m of longitudinal plus circumferential weld seam. In these cases the thickness of the test plate is to be equal to the thickest shell plate used in the construction.

4.6.3 Where the vessel size or design results in a small number of longitudinal weld seams, one test assembly may be prepared for testing provided that the welding details are the same for each seam.

4.6.4 Test plate materials are to be the same grade, thickness and supply condition and from the same cast as that of the vessel shell. The test assembly is to be welded at the same time as the vessel weld to which it relates and is to be supported so that distortion during welding is minimised.

4.6.5 As far as practicable, welding is to be performed by different welders where there is a requirement for several routine tests to be welded.

4.6.6 The test assembly may be detached from the vessel weld only after the Surveyor has performed a visual examination and has added his mark or stamp. Straightening of test welds prior to mechanical testing is not permitted.

4.6.7 Where the pressure vessel is required to be subjected to post-weld heat treatment, the test weld is to be heat treated, after welding, in accordance with the same requirements. This may be performed separately from the vessel.

4.7 Inspection and testing

4.7.1 The test weld is to be subjected to the same type of non-destructive examination and acceptance criteria as specified for the weld seam to which the test relates. Non-destructive examination is to be performed prior to removing specimens for mechanical testing, but after any post-weld heat treatment.

4.7.2 The test weld is to be sectioned to remove the number and type of test specimens for mechanical testing as given in 4.8.

4.8 Mechanical requirements

4.8.1 The routine production test assembly is to be machined to provide the following test specimens:
(a) Tensile.
(b) Bend.
(c) Hardness.
(d) Impact (*see* Table 13.4.1).
(e) Macrograph and hardness survey of full weld section.

4.8.2 One set of specimens for mechanical testing are to be removed, as shown in Figs. 13.4.1 or 13.4.2 as appropriate for the Class of approval. Impact tests are to be removed and tested where required by Table 13.4.1.

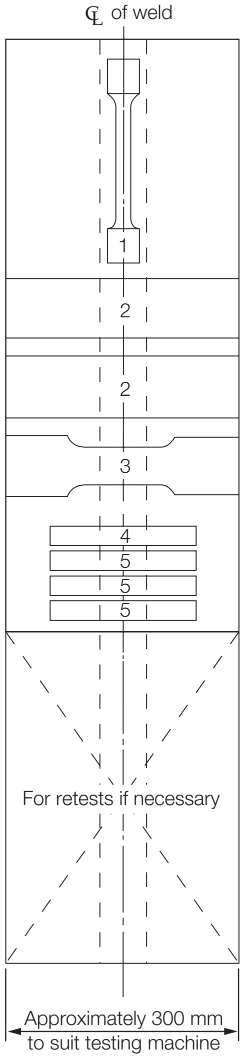
4.8.3 **Longitudinal tensile test for weld metal**. An all-weld metal longitudinal tensile test is required. For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, additional longitudinal tests are required from the respective area of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld. Specimens are to be tested in accordance with the following requirements:
(a) The diameter and gauge length of the test specimen is to be in accordance with Ch 11,2.1.1.
(b) For carbon and carbon-manganese steels the tensile strength of the weld metal is to be not less than the minimum specified for the plate material and not more than 145 N/mm^2 above this value. The percentage elongation, A, is to be not less than that given by:
A = (980-R)/21,6 but not less than 80 per cent of the minimum elongation specified for the plate

where
R is the tensile strength, in N/mm^2, obtained from the all weld metal tensile tests.
(c) For other materials the tensile strength and percentage elongation is not to be less than that specified for the base materials welded.

4.8.4 **Transverse tensile test for joint**. Transverse tensile test specimens are to be removed and tested in accordance with the following requirements:
(a) One reduced section tensile test specimen is to be cut transversely to the weld to the dimensions shown in Ch 11,2.1.1 and the weld reinforcement is to be removed.

Table 13.4.1 Impact test requirements

Pressure vessel Class	Minimum design temperature	Plate material thickness t	Impact test temperature
Class 1 *see* Note	–10°C or above	All	5°C below the minimum design temperature or 20°C, whichever is the lower
All Classes	Below –10°C	$t \leq 20$ mm	5°C below the minimum design temperature
		20 mm $< t \leq 40$ mm	10°C below the minimum design temperature
		Over 40 mm	Subject to special consideration
NOTE Impact testing is not required for Classes 2/1, 2/2 and 3.			

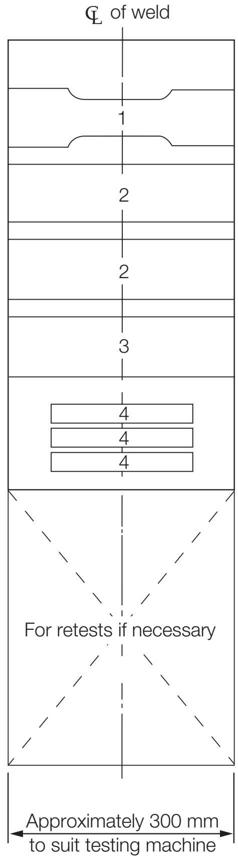


1. All weld metal tensile test specimen.
2. Bend test specimens.
3. Tensile test for joints.
4. Macro-test specimen.
5. Charpy V-notch impact.
(For all Class 1 pressure vessels and other Classes of pressure vessels where the minimum design temperature is below –10°C).

Fig. 13.4.1
Routine weld test – Test specimens for Class 1 and Class 2/1

(b) In general, where the plate thickness exceeds 30 mm, or where the capacity of the tensile test machine prevents full thickness tests, each tensile test may be made up of several reduced section specimens, provided that the whole thickness of the weld is subjected to testing.

(c) The tensile strength obtained is to be not less than the minimum specified tensile strength for the plate material, and the location of the fracture is to be reported.



1. Tensile test for joints.
2. Bend test specimens.
3. Nicked bend test specimen.
4. Charpy V-notch impact test specimens (if required by Table 13.4.1).

Fig. 13.4.2
Routine weld tests – Test specimens for Class 2/2 and Class 3

4.8.5 **Transverse bend test**. The bend test specimens are to be removed and tested in accordance with the following requirements:

(a) Two bend test specimens of rectangular section are to be cut transversely to the weld, one bent with the outer surface of the weld in tension (face bend), and the other with the inner surface in tension (root bend).

(b) The specimen dimensions are to be in accordance with Chapter 2.

(c) Each specimen is to be mounted on roller supports with the centre of the weld midway between the supports. The former is to have a diameter specified in Ch 12,2.7.6 depending on the material being welded.

(d) After bending through an angle of at least 180° there is to be no crack or defect exceeding 1,5 mm measured across the specimen or 3 mm measured along the specimen. Premature failure at the edges of the specimen is not to be cause for rejection, unless this is associated with a weld defect.

4.8.6 **Macro-specimen and hardness survey**. A macro examination specimen is to be removed from the test assembly near the end where welding started. The specimen is to include the complete cross-section of the weld and the heat affected zone. The specimen is to be prepared and examined in accordance with the following requirements:

(a) The cross-section of the specimen is to be ground, polished and etched to clearly reveal the weld runs, and the heat affected zones.
(b) The specimen is to show an even weld profile that blends smoothly with the base material and have satisfactory penetration and fusion, and an absence of significant inclusions or other defects.
(c) Where there is doubt in the condition of the weld as shown by macro-etching, the area concerned is to be microscopically examined.
(d) For carbon, carbon manganese and low alloy steels, a Vickers hardness survey is to be performed on the macro-specimen using either a 5 kg or 10 kg load. Testing is to include the base material, the weld and the heat affected zone. Hardness scans on the cross-section are to be performed as specified in Fig. 12.2.8 in Chapter 12. The maximum recorded hardness is to not exceed 350 Hv.

4.8.7 **Charpy V-notch impact test**. Charpy V notch impact test specimens are to be prepared and tested as required by Table 13.4.1 and in accordance with the following requirements:

(a) The dimensions and tolerances of the specimens are to be in accordance with Chapter 2.
(b) Charpy V-notch impact specimens and are to be removed with the notch perpendicular to the plate surface.
(c) Specimens are to be removed for testing from the weld centreline and the heat affected zone (fusion line and fusion line + 2 mm locations) detailed in Fig. 12.2.6 or Fig. 12.2.7 in Chapter 12, as appropriate. Heat affected zone impact tests may be omitted where the minimum design temperature is above +20°C.
(d) For thicknesses in excess of 20 mm, where more than one welding process or type of consumable has been used to complete the joint, impact tests are required from the respective areas of the weld. This does not apply to the welding process or consumables used solely to deposit the root weld.
(e) The average energy of a set of three specimens is not to be less than 27 J or the minimum specified for the base material, whichever is the higher. The minimum energy for each individual specimen is to meet the requirements of Ch 1,4.5.2.

4.8.8 **Nick break bend tests**. A nick bend or fracture test specimen is to be a minimum of 100 mm long measured along the weld direction and is to be tested in accordance with and meet the requirements of the following:

(a) The specimen is to have a slot cut into each side along the centreline of the weld and perpendicular to the plate surface.
(b) The specimen is to be bent along the weld centreline until fracture occurs and the fracture faces are to be examined for defects. The weld is to be sound, with no evidence of cracking or lack of fusion or penetration and be substantially free from slag inclusions and porosity.

4.9 Failure to meet requirements

4.9.1 Where any test specimen fails to meet the requirements, additional specimens may be removed and re-tested in accordance with Ch 2,1.4.

4.9.2 Where a routine weld test fails to meet requirements, the welds to which it relates will be considered as not having met the requirements. The reason for the failure is to be established, and the manufacturer is to take such steps as necessary to either

(a) Remove the affected welds and have them re-welded, or
(b) Demonstrate that the affected production welds have acceptable properties.

4.10 Heat treatment

4.10.1 Fusion welded pressure vessels, where indicated in Table 13.4.2, are to be heat treated on completion of the welding of the seams and of all attachments to the shell and ends, and before the hydraulic test is carried out.

4.10.2 Tubes which have been expanded into headers or drums may be seal welded without further post-weld heat treatment.

4.10.3 Steam and gas turbine cylinders and rotors are to be subjected to post-weld heat treatment irrespective of thickness.

4.10.4 Where the weld attaches parts of different thicknesses, the thickness to be used when applying the requirements for post-weld heat treatment is to be either the thinner of the two plates for butt welded connections, or the thickness of the shell for welds to flanges, tubeplates and similar connections.

4.10.5 Care is to be exercised to provide drilled holes in double reinforcing plates and other closed spaces prior to heat treatment.

4.11 Basic requirements for heat treatment of fusion welded pressure vessels

4.11.1 Recommended soaking temperatures and soak durations for post-weld heat treatment are given in Table 13.4.3 for different materials. Where other materials are used for pressure vessel construction, full details of the proposed heat treatment are to be submitted for consideration.

4.11.2 Where pressure vessels are of dimensions that the whole length cannot be accommodated in the furnace at one time, the pressure vessels may be heated in sections, provided that sufficient overlap is allowed to ensure the heat treatment of the entire length of the longitudinal seam.

4.11.3 Where materials other than those detailed in Table 13.4.3 are used or where it is proposed to adopt special methods of heat treatment, full particulars are to be submitted for consideration. In such cases, it may be necessary to carry out tests to show the effect of the proposed heat treatment.

Table 13.4.2 Post-weld heat treatment requirements

Type of steel	Plate thickness above which post-weld heat treatment (PWHT) is required	
	Steam raising plant	Other pressure vessels
Carbon and carbon/manganese steels without low temperature impact values	20 mm	30 mm
Carbon and carbon/manganese steels with low temperature impact values	20 mm	40 mm
1Cr ½Mo	All thicknesses	All thicknesses
2¼Cr 1Mo	All thicknesses	All thicknesses
½Cr ½Mo ¼V	All thicknesses	All thicknesses
Other alloy steels	Subject to special consideration	

Table 13.4.3 Post-weld soak temperatures and times

Material type	Soak temperature (°C)	Soak period
Carbon and carbon/manganese grades	580–620°	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	620–660°	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	650–690°	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	670–720°	1 hour per 25 mm of thickness, minimum of 1 hour
NOTE For materials supplied in the tempered condition, the post-weld heat treatment temperature is to be lower than the material tempering temperature.		

4.12 Non-Destructive Examination of welds

4.12.1 Non-Destructive Examinations (NDE) of pressure vessel welds are to be carried out in accordance with a nationally recognised code or standard.

4.12.2 NDE is not to be applied until an interval of at least 48 hours has elapsed since the completion of welding.

4.12.3 NDE Personnel are to be qualified to an appropriate level of a nationally recognised certification scheme.

4.12.4 Qualification schemes are to include assessments of practical ability for Levels I and II individuals. These examinations are to be made on representative test pieces containing relevant defects.

4.13 Extent of NDE for Class 1 pressure vessels

4.13.1 All butt welded seams in drums, shells, headers and test plates, together with tubes or nozzles with outside diameter greater than 170 mm, are subject to 100 per cent volumetric and surface crack detection inspections.

4.13.2 For circumferential butt welds in extruded connections, tubes, headers and other tubular parts with an outside diameter of 170 mm or less, at least 10 per cent of the total number of welds is to be subjected to volumetric examination and surface crack detection inspections.

4.13.3 Full penetration tube sheet to shell welds are to be subjected to 10 per cent volumetric examination and 10 per cent surface inspection, prior to the installation of the tubes.

4.13.4 In addition to the acceptance limits stated in Tables 13.2.4 to 13.2.6, no cracks, lack of fusion, or lack of penetration is permitted.

4.13.5 When an unacceptable indication is detected, the full length of the weld is to be subjected to 100 per cent examination by the same method, testing conditions and acceptance criteria.

4.14 Extent of NDE for Class 2/1 pressure vessels

4.14.1 For Class 2/1 pressure vessels, volumetric and surface crack detection inspections are to be applied at selected regions of each main seam. At least 10 per cent of each main seam is to be examined together with the full length of each welded test plate. When an unacceptable indication is detected, at least two additional check points in the seam are to be selected by the surveyor for examination using the same inspection method. Where further unacceptable defects are found either:

(a) the whole length of weld represented is to be cut out and re-welded and re-examined as if it was a new weld with the test plates being similarly treated, or

(b) the whole length of the weld represented is to be re-examined using the same inspection methods.

4.14.2 Butt welds in furnaces, combustion chambers and other pressure parts for fired pressure vessels under external pressure, are to be subject to spot volumetric examination. The minimum length for each check point is to be 300 mm.

4.14.3 The extent of NDE for turbine cylinders and rotors is to be agreed with the Surveyor.

4.14.4 The requirements of 4.13.3, 4.13.4 and 4.13.5 apply to Class 2/1 pressure vessels.

4.15 NDE Method

4.15.1 Volumetric examinations may be made by radiography. For welds of nominal thickness greater than or equal to 8 mm, the examinations may be by ultrasonic testing. The preferred method for surface crack detection in ferrous metals is magnetic particle inspection. The preferred method for non-magnetic materials is liquid penetrant inspection.

4.16 Evaluation and reports

4.16.1 The manufacturer is to be responsible for the review, interpretation, evaluation and acceptance of the results of NDE. Reports stating compliance, or non-compliance, with the criteria established in the inspection procedure are to be issued. Reports are to comply, as a minimum, with the requirements of Ch 1,5.

4.17 Repair to welds

4.17.1 Where non-destructive examinations reveal unacceptable defects in the welded seams, they are to be repaired in accordance with 1.15 and are to be shown by further non-destructive examinations to have been eliminated.

4.17.2 In the case where spot radiography has revealed unacceptable defects, the requirements of 4.14.1 apply.

4.17.3 Where post-weld heat treatment is required in accordance with 4.10, weld repairs to the vessel or cylindrical shell or parts attaching to the shell are to be subjected to a subsequent heat treatment in accordance with 4.10.

4.17.4 In the event of unsuccessful weld repair of a defect, only one more repair attempt may be made of the same defect. Any subsequent repairs may require the re-repair excavation to be enlarged to remove the original repair heat affected zone.

■ *Section 5* Specific requirements for pressure pipework

5.1 Scope

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of this Section and the general requirements given in Section 1, unless more stringent requirements have been specified.

5.1.2 Piping systems are to be constructed in accordance with the approved plans and specifications.

5.1.3 Fabricated pipework will be accepted only if manufactured by firms that have demonstrated that they have the facilities and equipment and are competent to undertake the quality of welding required for the Class of pipework proposed.

5.2 Manufacture and workmanship

5.2.1 Pipe welding may be performed using manual, semi-automatic or fully automatic electric arc processes. The use of oxy-acetylene welding will be limited to Class 3 pipework in carbon steel or carbon/manganese material that is not for carrying flammable fluids and limited to butt joints in pipes not exceeding 100 mm diameter or 9,5 mm thickness.

5.2.2 Welding of pipework, including attachment welds directly to pressure retaining parts is to be performed in accordance with approved welding procedures that have been qualified in accordance with Chapter 12.

5.2.3 Where the work involves a significant number of branch connections, tests will be required to demonstrate that the type of joint(s) and welding techniques employed are capable of achieving the required quality.

5.2.4 Where pressure pipework is assembled and butt welded insitu, the piping is to be arranged well clear of adjacent structures to allow sufficient access for preheating, welding, heat-treatment and non-destructive examination of the joints.

5.2.5 Alignment of pipe butt welds is to be in accordance with Table 13.5.1 unless more stringent requirements have been agreed. Where fusible inserts are used, the alignment is to be within 0,5 mm in all cases.

5.2.6 The number of welds is to be kept to a minimum. The minimum separation between welds, measured toe-to-toe, is to be not be less than 75 mm. Where it is not possible to achieve this, adjacent welds are to be subjected to surface crack detection NDE.

5.2.7 Welding consumables and fusible root inserts, where used, are to be suitable for the materials being joined.

Table 13.5.1 Pipe butt weld alignment tolerances

Pipe size	Maximum permitted misalignment
D < 150 mm and $t \leq 6$ mm	1,0 mm or 25% of t, whichever is the lesser
D < 300 mm and $t \leq 9,5$ mm	1,5 mm or 25% of t, whichever is the lesser
$D \geq 300$ and $t > 9,5$ mm	2,0 mm or 25% of t, whichever is the lesser
where D = pipe internal diameter t = pipe wall thickness	

5.2.8 Acceptable methods of flange attachment are to be used, *see* Fig. 12.2.2 in Pt 5, Ch 12 of the Rules for Ships. Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and be removed after welding. The rings are to be made of the same material as the pipes. The use of flange types (b) and (c) with alloy steel pipes is limited to pipes up to and including 168,3 mm outside diameter.

5.2.9 Where socket welded fittings are employed, the diametrical clearance between the outside diameter of the pipe and the base of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the internal step at the bottom of the socket.

5.2.10 For welding of carbon, carbon/manganese and low alloy steels, the preheat to be applied will be dependent on the material grade, thickness and hydrogen grading of the welding consumable in accordance with Table 13.5.2, unless welding procedure testing indicates that a higher level is required.

5.2.11 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.12 All welds in high pressure, high temperature pipelines are to have a smooth surface finish and even contour; and where necessary, made smooth by grinding.

5.2.13 Check tests of the quality of the welding are to be carried out periodically.

5.3 Heat treatment after bending of pipes

5.3.1 After forming or bending of pipes, the heat treatments specified in this Section are to be applied unless the pipe material manufacturer specifies or recommends other requirements.

5.3.2 Generally, hot forming is to be carried out within the normalising temperature range. When carried out within this temperature range, no subsequent heat treatment is required for carbon and carbon/manganese steels. For alloy steels, 1Cr ½Mo, 2¼Cr 1Mo and ½Cr ½Mo ¼V, a subsequent tempering heat treatment in accordance with the temperatures and times specified in Table 13.5.3 is required, irrespective of material thickness.

5.3.3 When hot forming is performed outside the normalising temperature range, a subsequent heat treatment in accordance with Table 13.5.3 is required.

5.3.4 After cold forming to a radius (measured at the centreline of the pipe) of less than four times the outside diameter, heat treatment in accordance with Table 13.5.3 is required.

5.3.5 Heat treatment should be carried out in accordance with 1.16.

Table 13.5.2 Welding preheat levels for pipework

Material Grade	Thickness, t (mm) *see* Note 4	Minimum preheat temperature (°C) *See* Note 1	
		Non-low H_2	Low H_2 *see* Note 2
Carbon and carbon/manganese grades: 320 and 360	$t \leq 15$ $t \geq 15$	50 100	10 50
Carbon and carbon/manganese grades: 410, 460 and 490	$t \leq 15$ $t \geq 15$	75 150	20 100
1Cr ½Mo	$t < 13$ $t \geq 13$	*See* Note 3	100 150
2¼Cr 1Mo	$t < 13$ $t \geq 13$	*See* Note 3	150 200
½Cr ½Mo ¼V	$t < 13$ $t \geq 13$	*See* Note 3	150 200

NOTES
1. Where the ambient temperature is 0°C or below, pre-warming of the weld joint is required in all cases.
2. Low hydrogen process or consumables are those that have been tested and have achieved a grading of H15 or better (*see* Chapter 11).
3. Low hydrogen welding process is required for these materials.
4. t = the thickness of the thinner member for butt welds, and the thicker member for fillet and branch welds.

Table 13.5.3 Heat treatment after bending of pipes

Type of steel	Heat treatment required
Carbon and carbon/manganese: Grades 320, 360, 410, 460 and 490	Normalise at 880 to 940°C
1Cr ½Mo	Normalise at 900 to 940°C, followed by tempering at 640 to 720°C
2¼Cr 1Mo	Normalise at 900 to 960°C, followed by tempering at 650 to 780°C
½Cr ½Mo ¼V	Normalise at 930 to 980°C, followed by tempering at 670 to 720°C
Other alloy steels	Subject to special consideration

5.3.6 Bending procedures and subsequent heat treatment for other alloy steels will be subject to special consideration.

5.4 Post-weld heat treatment

5.4.1 Post-weld heat treatment is to be carried out in accordance with the general requirements specified in 1.16 and 4.10.

5.4.2 The thickness limits, the recommended soaking temperatures and periods, for application of post-weld heat treatment are given in Table 13.5.4.

5.4.3 Where the use of oxy-acetylene welding is proposed, due consideration is to be given to the need for normalising and tempering after such welding.

5.5 Non-destructive examination

5.5.1 Non-destructive examination of pipe welds is to be carried out in accordance with the general requirements of 1.11 and the following.

5.5.2 Butt welds in Class 1 pipes with an outside diameter greater or equal to 75 mm are to be subject to 100 per cent volumetric and visual inspections. Consideration is to be given to the extent and method of testing applied to butt welds in Class 1 pipes with an outside diameter less than 75 mm.

5.5.3 Butt welds in Class II pipes are to be subjected to at least 10 per cent random volumetric inspections when the outside diameter is greater than 100 mm.

5.5.4 NDE for Class II pipes with a diameter less than 100 mm is to be at the discretion of the Surveyor.

5.5.5 Non-destructive examination procedures, methods and the evaluation of reports are to be in accordance with 4.15 and 4.16.

5.5.6 Fillet welds on flange pipe connections of Class I pipes are to be examined by surface crack detection methods.

5.6 Repairs to pipe welds

5.6.1 Where non-destructive examinations reveal unacceptable defects in a weld, the defects are to be removed and repaired in accordance with 1.15. Completed repairs are to be shown by further non-destructive examination to have eliminated the defects.

5.6.2 For pipes with diameter less than 88 mm and where unacceptable defects have been found during non-destructive examination, consideration is to be given to cutting the weld out completely, re-making the weld preparation and re-welding as a new joint (because of the difficulty of making small repairs).

Table 13.5.4 Post-weld heat treatment requirements for pipework

Material Grade	Thickness for which post-weld heat treatment is required	Soak temperature (°C) *see* Note 2	Soak period
Carbon and carbon/manganese grades: 320, 360, 410, 460, 490	Over 30 mm	580–620°C	1 hour per 25 mm of thickness, minimum of 1 hour
1Cr ½Mo	Over 8 mm	620–660°C	1 hour per 25 mm of thickness, minimum of 1 hour
2¼Cr 1Mo	All	650–690°C	1 hour per 25 mm of thickness, minimum of 1 hour
½Cr ½Mo ¼V	All, *see* Note 1	670–720°C	1 hour per 25 mm of thickness, minimum of 1 hour

NOTES
1. Heat treatment may be omitted for thicknesses up to 8 mm and diameters not exceeding 100 mm provided welding procedure tests have demonstrated acceptable properties in the as welded condition.
2. For materials supplied in the tempered condition, the post weld heat treatment temperature is to be at least 20°C less than the material tempering temperature.

5.6.3 Where repeated weld repairs have to be made to a weld, only two such attempts are to be permitted, thereafter the weld is to be cut apart and removed, and re-welded as a new joint.

5.6.4 Where pipework requires post-weld heat treatment weld, repairs to the pressure retaining parts are to be subjected to a subsequent heat treatment. Similarly, where welding is conducted after pressure testing, a further pressure test is to be required unless specific exemption has been agreed.

■ *Section 6* Repair of existing ships by welding

6.1 Scope

6.1.1 This Section specifies requirements for repairs made by welding after introduction into service. This Section includes defects to hull structures, machinery, equipment and components. It also includes replacement of structure due to damage or corrosion. These requirements are in addition to those specified in the preceding Sections of this Chapter.

6.1.2 These requirements apply unless the original builder or manufacturer has specified alternative requirements.

6.2 Materials used for repairs

6.2.1 Permanent materials used in the repair are to be in accordance with 1.3.

6.2.2 Prior to commencing any welding, the material grades present in the original structure in way of the repair are to be determined. Where the materials cannot be identified from the ship records, test samples may be removed for chemical analysis and mechanical testing in order to determine the material grades.

6.2.3 Temporary materials that are to be welded to the main structure to assist in executing the repairs, but removed on completion, are to be of weldable quality.

6.3 Workmanship

6.3.1 A repair method is to be established by the shipyard or repair yard and is to be agreed by the Surveyor prior to commencing any repair work.

6.3.2 The removal of crack-like defects is to be confirmed by visual examination and surface crack detection NDE. This may be augmented by ultrasonic examination where several defects are reported at different depths at the same location.

6.3.3 The weld joint or groove shape used for the repair is to have a profile suitable for welding.

6.3.4 The weld area is to be carefully cleaned, in particular, where the material surface has been painted or has been subjected to an oily or greasy environment.

6.4 Non-destructive examination

6.4.1 On completion of welding and any post-weld heat treatment, repair welds are to be subjected to the type and extent of NDE and assessed in accordance with the acceptance criteria specified for the original construction.

6.4.2 Where the original construction specification did not specify NDE, the completed welds are to be, as a minimum, subject to visual examination. Consideration of other NDE techniques is to take due cognisance of the location or the repair within the vessel.

6.4.3 Where spot NDE is applied and defects are found, the extent of NDE is to be increased to include an equal amount of weld length. Where this reveals unacceptable defects, either the whole weld will be rejected or the extent of inspection increased to 100 per cent examination.

6.4.4 The acceptance criteria to be applied are to generally be in accordance with the original build specification. Where conflict of requirements exist, the NDE acceptance limits for welding procedure tests specified in Ch 12,2.5.5 may be used as a minimum requirement.

6.5 Repairs to welds defects

6.5.1 Where NDE reveals unacceptable defects, these are to be repaired in accordance with 1.15.

■ *Section 7* Austenitic and duplex stainless steel – Specific requirements

7.1 Scope

7.1.1 This Section specifies requirements for the fabrication and welding of austenitic and duplex stainless steels, and is in addition to those detailed above.

7.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

7.1.3 All tools and equipment used are to be suitable for use on stainless steel materials. The use of tools or equipment made of carbon steel materials is to be avoided. It is permissible to use carbon steel tools provided that the surfaces that come into contact with the austenitic and duplex stainless materials are protected with an austenitic or nickel base alloy.

7.2 Design

7.2.1 Care is to be exercised in the weld design to prevent crevice corrosion from occurring, particularly where austenitic materials are used. In this respect fillet welds and partial penetration welds are to be continuous and welded on both sides of the joint.

7.3 Forming and bending

7.3.1 Materials that are cold formed, such that the total strain exceeds 15 per cent (i.e. where the formed diameter to thickness ratio is less than 6:1) are to be subjected to a subsequent softening heat treatment in accordance with the material manufacturers recommendations, unless it is demonstrated by testing that the material properties are acceptable in the 'as formed' condition.

7.3.2 Materials may be hot formed provided that a subsequent softening heat treatment is carried out. The forming process and the subsequent heat treatment are to be in accordance with the material manufacturer's recommendations.

7.4 Fabrication and welding

7.4.1 Welding may be performed using shielded manual arc welding (SMAW), gas tungsten arc welding (GTAW), MIG/MAG welding (GMAW), flux cored arc welding (FCAW), plasma arc welding (PAW) and submerged arc welding (SAW). The use of other welding processes will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

7.4.2 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

7.4.3 For full penetration welds, a backing or shielding gas is to be provided to prevent oxidation of the root weld. The backing gas is to be maintained until completion of, at least, the root and first fill layer. The backing gas may be omitted where the weld is back gouged or ground to remove the root weld.

7.4.4 Shielding and backing gases are to be an inert type of high purity and oxygen free.

7.4.5 For welding of Duplex stainless, the use of backing gases that contain up to 2 per cent nitrogen is permitted.

7.4.6 Welding of duplex stainless steels without filler metal is generally not permitted.

7.4.7 Degreasing agents, acid solutions, washing water etc. used for cleaning and any marking crayons and paints used are to be free of chlorides.

7.5 Repairs

7.5.1 Correction of distortion by the application of heat is not permitted.

■ *Section 8*
Specific requirements for welded aluminium

8.1 Scope

8.1.1 This Section specifies requirements for the fabrication and welding of aluminium alloys, and is in addition to those detailed in this Chapter.

8.1.2 Fabrication and welding of these materials is to be in designated areas which are separated from those used for other materials, such as carbon steels, stainless steels and copper alloys. Where work is performed in the same workshop as other materials, adequate barriers or screening are to be provided to prevent cross-contamination of different material types.

8.1.3 All tools and equipment used are to be suitable for use on aluminium alloy materials. The use of tools made of carbon steel materials is to be avoided where possible.

8.2 Forming and bending

8.2.1 Aluminium alloys are to be subject to cold forming and cold bending only.

8.3 Fabrication and welding

8.3.1 Welding may be performed using gas tungsten arc welding (GTAW) or metal inert gas welding (GMAW), MIG/MAG welding (GMAW), or variants thereof. The use of other welding processes such as friction stir welding (FSW) will be subject to special consideration and will require submission of the process details, consumables and the weld properties achieved.

8.3.2 A comparison of the mechanical properties for selected welded and unwelded alloys is given in Table 13.8.1.

8.3.3 Misalignment may be corrected by the application of steady even force (e.g., using hydraulic or screw-type clamps). Hammering or heating is not permitted.

8.3.4 Correction of distortion by the application of heat is not permitted.

8.4 Non-destructive examination

8.4.1 The requirements of Ch 13,1.11 and Ch 13,2.12 apply; however, acceptance criteria applicable to aluminium are to be in accordance with Table 13.8.2 and Table 13.8.3.

Table 13.8.1 Minimum mechanical properties for aluminium alloys

Alloy	Condition		0,2% proof stress, N/mm^2		Ultimate tensile strength, N/mm^2	
			Unwelded	Welded (*see* Note 4)	Unwelded	Welded (*see* Note 4)
5083	O/H111		125	125	275	275
5083	H112		125	125	275	275
5083	H116/H321		215	125	305	275
5383	O/H111		145	145	290	290
5383	H116/H321		220	145	305	290
5086	O/H111		100	95	240	240
5086	H112		125 (*see* Note 2)	95	250 (*see* Note 2)	240
5086	H116/H321		195	95	275	240
5059	O/H111		160	160	330	330
5059	H116/H321		260	160	360	300
5456	O		125	125	285	285
5456	H116		200 (*see* Note 5)	125	290 (*see* Note 5)	285
5456	H321		215 (*see* Note 5)	125	305 (*see* Note 5)	285
5754	O/H111		80	80	190	190
6005A (see Note 1)	T5/T6	Extruded: Open Profile Extruded: Closed Profile	215 215	100 100	260 250	160 160
6061 (see Note 1)	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 240 205	125 125 125	290 260 245	160 160 160
6082	T5/T6	Rolled Extruded: Open Profile Extruded: Closed Profile	240 260 240	125 125 125	280 310 290	190 190 190

NOTES
1. These alloys are not normally acceptable for application in direct contact with sea-water.
2. See also Table 8.1.3 or Table 8.1.4 in Chapter 8.
3. The mechanical properties to be used to determine scantlings in other types and grades of aluminium alloy manufactured to National or proprietary standards and specifications are to be individually agreed with LR, *see also* Ch 8,1.1.5.
4. Where detail structural analysis is carried out, 'unwelded' stress values may be used away from heat affected zones and weld lines, *see also* Pt 3, Ch 2, 1.1.3 of the Rules for Ships.
5. For thickness less than 12,5 mm, the minimum unwelded 0,2% proof stress is to be taken as 230 N/mm^2 and the minimum tensile strength is to be taken as 315 N/mm^2.

8.4.2 Alternative NDE acceptance criteria will be subject to special consideration provided that they are equivalent to these requirements.

Table 13.8.2 Acceptance criteria for surface imperfections of aluminium

Surface discontinuity	Classification according to ISO 6520-1	Acceptance criteria
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete root penetration in butt joints welded from one side	4021	Not permitted
Surface pore	2017	$d \leq 0{,}3s$ or $0{,}3a$ or 1,5 mm (whichever is the lesser)
Linear porosity (*see* Note 1)	2014	Not permitted
Uniformly distributed porosity (*see* Note 2)	2012	≤ 1% of area
Clustered porosity	2013	Not permitted
Continuous undercut	5011	$h \leq 0{,}1t$ or 0,5 mm (whichever is the lesser)
Intermittent undercut	5012	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Excess weld metal (*see* Note 3)	502	$h \leq 1{,}5$ mm + $0{,}15b$ or 8 mm (whichever is the lesser)
Excess penetration	504	$h \leq 4$ mm
Root concavity (*see* Note 3)	515	$h \leq 0{,}1t$ or 1 mm (whichever is the lesser)
Linear misalignment (*see* Notes 4 and 5)	507	$h \leq 0{,}1t$ or 1,0 mm (whichever is the lesser)
Angular misalignment	508	(*see* Note 6)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)

NOTES
1. For these acceptance criteria, linear porosity is to be considered as three aligned gas pores in a length of 25 mm.
2. To be in accordance with EN ISO 10042.
3. A smooth transition is required.
4. Linear misalignment is to be a maximum of 0,5 mm in highly stressed areas. For other areas, the linear misalignment is to be a maximum of 1,0 mm locally, where the sum of the length of imperfection is not more than 10% of the weld length.
5. The limits for linear misalignment relate to deviations from the correct position. Unless otherwise specified, the correct position is that when the centrelines coincide.
6. Angular misalignment shall be mutually agreed between the designer and the fabricator.

Table 13.8.3 Acceptance criteria for internal imperfections of aluminium

Internal discontinuity	Classification according to ISO 6520-1	Acceptance criteria (*see* Note 1)
Crack	100	Not permitted
Lack of fusion	401	Not permitted
Incomplete penetration	402	Not permitted
Single gas pore	2017	$d \leq 0,3s$ or $0,3a$ or 5 mm (whichever is the lesser)
Linear porosity	2014	Assess as lack of fusion
Uniformly distributed porosity (*see* Note 1)	2012	$0,5 < t < 3$ mm ≤ 2% of area $3 < t < 12$ mm ≤ 4% of area $12 < t < 30$ mm ≤ 6% of area $t > 30$ mm ≤ 8% of area
Clustered porosity (*see* Note 1)	2013	$dA \leq 20$ mm or wp (whichever is the lesser)
Elongated cavity Wormhole	2015 2016	$l \leq 0,3s$ or $0,3a$ or 4 mm (whichever is the lesser)
Oxide inclusion (*see* Note 2)	303	$l \leq 0,5s$ or $0,5a$ or 5 mm (whichever is the lesser)
Tungsten inclusion	3041	$l \leq 0,3s$ or $0,3a$ or 4 mm (whichever is the lesser)
Copper inclusion	3042	Not permitted
Multiple imperfections in any cross-section	—	The sum of the acceptable individual imperfections in any cross-section is not to exceed $0,3t$ or $0,3a$ (whichever is the lesser)

Symbols

a = nominal throat thickness of a fillet weld
b = width of weld reinforcement
d = diameter of a gas pore
h = height or width of an imperfection
s = nominal butt weld thickness
t = wall or plate thickness (nominal size)
wp = width of weld or width or height of cross-sectional area
dA = diameter of area surrounding gas pores
l = length of imperfection in longitudinal direction of weld

NOTES
1. Porosity is to be determined in accordance with ISO 10042. The requirements for a single gas pore are to be met by all the gas pores within this circle. Systematic clustered porosity is not permitted.
2. If several oxide inclusions l_1, l_2, l_3, ... exist in one cross-section, then they are summed: $l = l_1 + l_2 + l_3 + ... + l_n$.

■ *Section 1*
General requirements

1.1 Scope

1.1.1 Provision is made in this Chapter for the manufacture and testing of plastics pipes, together with approval requirements for base materials used in the construction or repair of composite vessels, other marine structures, piping and any associated machinery components and fittings which are to be certified or are intended for classification.

1.1.2 These materials and products are to be manufactured and surveyed in accordance with the general requirements of Sections 1, 2 and 3 of this Chapter; and LR's *Materials and Qualification Procedures for Ships (MQPS) Book K*, *see* Ch 1,2.2.2, which, in addition to the test programme, also details the procedures for application for approval of manufacturers and products and details of the information to be supplied by the manufacturer.

1.1.3 For base materials, the manufacturer's works do not require approval by Lloyd's Register (hereinafter referred to as 'LR'), however the Quality Control procedures must be acceptable in accordance with the appropriate Section of this Chapter.

1.1.4 Where a requirement exists for the material to be approved, the test requirements and information to be submitted for approval of polymers, resins, reinforcements and associated materials are defined in Sections 2 and 3.

1.1.5 Specific material requirements relating to the design and manufacture of plastics pipes and fittings are indicated in Section 4, with the material requirements for hull structures contained in Section 5.

1.1.6 For Builders constructing composite vessels, Section 5 provides the minimum material control requirements for acceptance of the works by LR.

1.1.7 For the purposes of these Rules a 'plastics material' is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives.

1.1.8 Materials not listed in 2.1.1 may be considered for approval on a case-by-case basis. The approved test results will be listed on the issued certificate. Subject to satisfactory service experience and validation of approval, the material may be entered in 2.1.1 of the Rules.

1.2 Information on material quality and application

1.2.1 Where plastics products are to be classed or certified, the manufacturer is to provide the material producer with such information as is essential to ensure that the base materials to be used are in accordance with the approval requirements and the product specification. This information is to include any survey requirements for the materials.

1.3 Manufacture

1.3.1 Plastics products are to be made at works which have been approved (or accepted) for the type of product being supplied using base materials that have been approved.

1.3.2 Base materials are to be approved in accordance with the requirements of Sections 2 and 3.

1.3.3 In order that a works can be approved (or accepted), the manufacturer is required to demonstrate to the satisfaction of LR that the necessary manufacturing and testing facilities are available and are supervised by qualified personnel. A specified programme of tests is to be carried out under the supervision of the Surveyors, and the results are to be to the satisfaction of LR. When a manufacturer has more than one works, the approval (or acceptance) is only valid for the individual works which carried out the test programme.

1.3.4 In order to maintain approval, the manufacturer is required to confirm in writing that there have been no changes in the formulation or production process for the material in question and that the site of manufacture remains unchanged.

1.4 Survey procedure

1.4.1 The Surveyors are to be allowed access to all relevant parts of the works and are to be provided with the necessary facilities and information to enable them to verify that manufacture is being carried out in accordance with the approved procedure. Facilities are also to be provided for the selection of test material, the witnessing of specified tests and the examination of materials, as required by the Rules.

1.4.2 Prior to the provision of test material for acceptance, manufacturers are to provide the Surveyors with details of the order, specification and any special conditions additional to the Rule requirements.

1.4.3 Before final acceptance, all test materials are to be confirmed as typical of the manufactured product and be submitted to the specified tests and examinations under conditions acceptable to the Surveyors. The results are to comply with the specification and any Rule requirements and are to be to the satisfaction of the Surveyors.

1.4.4 These specified tests and examinations are to be carried out prior to the despatch of finished products from the manufacturer's works.

1.4.5 In the event of any material proving unsatisfactory, during subsequent working, machining or fabrication, it is to be rejected, notwithstanding any previous certification.

1.5 Alternative survey procedure

1.5.1 Where materials are manufactured in quantity by semi-continuous or continuous processes under closely controlled conditions, an alternative system for testing and inspection may be adopted, subject to the agreement of the Surveyors.

1.5.2 In order to be considered for approval, manufacturers are to comply with the requirements of Ch 1,2.

1.6 Post-cure heating

1.6.1 Post-cure heating is to be carried out in properly constructed ovens which are efficiently maintained and have adequate means for control and recording of temperature. The oven is to be such as to allow the whole item to be uniformly heated to the necessary temperature. In the case of very large components which require post-cure heating, alternative methods will be specially considered.

1.7 Test material

1.7.1 Sufficient material is to be provided for the preparation of the test specimens detailed in the specific requirements. It is, however, in the interests of manufacturers to provide additional material for any re-tests which may be necessary, as insufficient or unacceptable test material may be a cause for rejection.

1.7.2 Where test materials, (either base materials or product sample materials) are selected by the Surveyor or a person nominated by LR, these are to be suitably identified by markings which are to be maintained during the preparation of the test specimens.

1.7.3 All base material samples for testing are to be prepared under conditions that are as close as possible to those under which the product is to be manufactured. Where this is not possible, a suitable procedure is to be agreed with the Surveyor.

1.7.4 During production, check test samples are to be provided as requested by the Surveyor.

1.7.5 Should the taking of these samples prove impossible, model samples are to be prepared concurrently with production. The procedure for the preparation of these samples is to be agreed with the Surveyor.

1.7.6 The dimensions, number and orientation of test specimens are to be in accordance with the requirements of a National or International Standard acceptable to LR.

1.8 Re-test procedure

1.8.1 Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.

1.8.2 Where an individual test result in a group, (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

1.9 Visual and non-destructive examination

1.9.1 Prior to the final acceptance, surface inspection, verification of dimensions and non-destructive examination are to be carried out in accordance with the requirements detailed in Sections 3, 4 and 5 of this Chapter.

1.9.2 When there is visible evidence to doubt the soundness of any material or component, such as flaws or suspicious surface marks, it is to be the responsibility of the manufacturer to prove the quality of the material by any suitable method.

1.10 Rectification of defective material

1.10.1 Small surface blemishes may be removed by mechanical means provided that, after such treatment, the dimensions are acceptable, the area is proved free from structural defects and the rectification has been completed to the satisfaction of the Surveyor.

1.10.2 Repair procedures for larger defects are to be agreed with LR prior to implementation.

1.11 Identification of products and base materials

1.11.1 The manufacturer of approved materials is to identify each batch with a unique number.

1.11.2 The manufacturer of plastics products is to adopt a system of identification which will enable all finished products to be traced to the original batches of base materials. Surveyors are to be given full facilities for tracing any component or material when required.

1.11.3 When any item has been identified by the personal mark of a Surveyor, or deputy, this is not to be removed until an acceptable new identification mark has been made by a Surveyor. Failure to comply with this condition will render the item liable to rejection.

1.11.4 Before any pipe or fitting is finally accepted it is to be clearly marked by the manufacturer in at least one place with the particulars detailed in the appropriate specific requirements as given in Section 4.

1.11.5 Where a number of identical items are securely fastened together in bundles, the manufacturer need only brand the top item of each bundle. Alternatively, a durable label giving the required particulars may be attached to each bundle.

1.12 Certification

1.12.1 Certification of the finished product is to be in accordance with the requirements of the appropriate Sections.

■ *Section 2* Tests on polymers, resins, reinforcements and associated materials

2.1 Scope

2.1.1 This Section gives the tests and data required by LR for materials approval and/or inspection purposes on the following:
(a) Thermoplastic polymers.
(b) Thermosetting resins.
(c) Reinforcements.
(d) Reinforced thermoplastic polymers.
(e) Reinforced thermosetting resins.
(f) Core materials.
  (i) End-grain balsa.
  (ii) Rigid foams.
  (iii) Synthetic felt type materials.
(g) Machinery chocking compounds.
(h) Rudder and pintle bearings.
(j) Stern tube bearings.
(k) Plywoods.
(l) Adhesive and sealant materials.
(m) Repair compounds.

2.2 Thermoplastic polymers

2.2.1 The following data is to be provided by the manufacturer for each thermoplastic polymer:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Bulk density.
(e) Filler content, where applicable.
(f) Pigment content, where applicable.
(g) Colour.

2.2.2 Samples for testing are to be prepared by moulding or extrusion under the polymer manufacturer's recommended conditions.

2.2.3 The following tests are to be carried out on these samples:
(a) Tensile stress at yield and break.
(b) Modulus of elasticity in tension.
(c) Tensile strain at yield and break.
(d) Compressive stress at yield and break.
(e) Compressive modulus.
(f) Temperature of deflection under load.
(g) Determination of water absorption.

2.3 Thermosetting resins

2.3.1 The data listed in Table 14.2.1 is to be provided by the manufacturer for each thermosetting resin.

Table 14.2.1 Data requirements for thermosetting resins

Data	Type of resin		
	Polyester (*see* Note 3 for vinylester)	Epoxide	Phenolic
Specific gravity of liquid resin	required	required	required
Viscosity	required	required	required
Gel time	required	required	not applicable
Appearance	required	required	required
Mineral content (*see* Note 1)	required	required	not applicable (*see* Note 2)
Volatile content	required	not applicable	not applicable
Acid value	required	not applicable	not applicable
Epoxide content	not applicable	required	not applicable
Free phenol	not applicable	not applicable	required
Free formaldehyde	not applicable	not applicable	required

NOTES
1. This is to be the total filler in the system, including thixotrope, filler, pigments, etc., and is to be expressed in parts by weight per hundred parts of pure resin.
2. If the resin is pre-filled, the mineral content is required.
3. Vinylesters are to be treated as equivalent to polyesters.

2.3.2 Cast samples are to be prepared in accordance with the manufacturer's recommendations and are to be cured and post-cured in a manner consistent with the intended use. The curing system used and the ratio of curing agent (or catalyst) to resin are to be recorded. Where post-cure conditions equivalent to ambient-cure conditions apply, *see* 3.2.2 and 3.2.3.

2.3.3 The following are to be determined using these samples:
(a) Tensile strength (stress at maximum load) and stress at break.
(b) Tensile strain at maximum load.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Temperature of deflection under load.
(e) Barcol hardness.
(f) Determination of water absorption.
(g) Volume shrinkage after cure.
(h) Specific gravity of cast resin.

2.3.4 In addition, for gel coat resins the stress at break and modulus of elasticity in flexure are to be determined.

2.3.5 Where resins which have been modified by the addition of waxes or polymers, for example 'low styrene emission or air inhibited' materials, it is to be confirmed that the use of such resins will not result in poor interlaminar adhesion when interruptions to the laminating process occur. The test procedure is to be as follows:
(a) A conventional room temperature curing catalyst/accelerator system is to be used with the resin for laminate preparation.
(b) A laminate of 25 to 35 per cent glass content in mass is to be prepared using two plies of 450 g/m^2 chopped strand mat. The laminate is to be prepared at ambient temperature (18° to 21°C). The laminate is to be allowed to stand for a minimum of four days but no longer than 6 days at ambient temperature.
(c) A further two plies of 450 g/m^2 chopped strand mat are to be laminated onto the exposed surface and cured at ambient temperature for 24 hours. The finished laminate is then to be post-cured at 40°C for 16 hours. The finished laminate is to have a glass content of 25 to 35 per cent.
(d) After cooling, the apparent interlaminar shear strength of the laminate is to be determined in accordance with ISO 14130; the minimum value is given in Table 14.5.5. Before testing the samples shall be conditioned at 23°C and relative humidity of 50 per cent for a period of 88 hours before testing.
(e) If the tests are undertaken at the resin manufacturer's own laboratory, the individual test values are to be reported and the broken test specimens retained for examination by LR.

Alternative test procedures will be considered with prior agreement.

2.4 Reinforcements

2.4.1 The following data is to be provided, where applicable, for each type of reinforcement:
(a) Reinforcement type.
(b) Fibre type for each direction.
(c) Fibre tex value.
(d) Fibre finish and/or treatment.
(e) Yarn count in each direction.
(f) Width of manufactured reinforcement.
(g) Weight per unit area of manufactured reinforcement.
(h) Weight per linear metre of manufactured reinforcement.
(j) Compatibility (e.g. suitable for polyesters, epoxides, etc.).
(k) Constructional stitching – details of yarn, specific gravity, type, frequency and direction.
(l) Weave type.
(m) Binder type and content.
(n) Density of the fibre material.

2.4.2 Tests of the mechanical properties are to be made on laminate samples containing the reinforcement and prepared as follows:
(a) an approved resin of suitable type is to be used;
(b) a minimum of three layers of the reinforcement is to be laid with parallel ply to give a laminate not less than 4 mm thick;
(c) the weights of resin and reinforcement used are to be recorded together with the measured thickness of the laminate, including the measured weight per unit area of the reinforcement used;
(d) for glass reinforcements, the glass/resin ratios, by weight, as shown in Table 14.2.2 are to be used;
(e) for reinforcement type other than glass, a fibre volume fraction, as shown in Table 14.2.3, is to be used.

2.4.3 Rovings intended for filament winding are to be tested as unidirectional rovings.

2.4.4 The following tests as defined in Section 3 are to be made on the samples:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Tensile secant modulus at 0,5 per cent and 0,25 per cent strain respectively.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Apparent interlaminar shear.
(j) Fibre content.
(k) Determination of water absorption.

Table 14.2.2 Glass fraction by weight for different reinforcement types

Reinforcement type	Glass fraction nominal values
Unidirectional	0,60
Chopped strand mat	0,30
Woven roving	0,50
Woven cloth	0,50
Composite roving (*see* Note)	0,45
Gun rovings	0,33
±45° stitched parallel plied roving	0,50
Triaxial parallel plied roving	0,50
Quadriaxial parallel plied roving	0,50

NOTE
Continuous fibre reinforcement with attached chopped strand mat.

Table 14.2.3 Content by volume for different reinforcement types

Reinforcement type	Content by volume nominal values
Unidirectional	0,41
Chopped strand mat	0,17
Woven roving	0,32
Woven cloth	0,32
Composite roving (*see* Note)	0,28
Gun rovings	0,19
±45° stitched parallel plied roving	0,32
Triaxial parallel plied roving	0,32
Quadriaxial parallel plied roving	0,32

NOTE
The volume content may be converted to weight fractions by use of the formula:

$W_F = V_F D_F/(D_F V_F + D_R V_R)$

where

W_F = fibre fraction by weight
D_F = density of fibre
D_R = density of cured resin
V_F = fibre fraction by volume
V_R = resin fraction by volume

2.4.5 The laminate is to be tested in air in the directions indicated by Table 14.2.4.

2.4.6 Additionally, tests in 2.4.4(c) and (f) are to be repeated, in one direction only, after immersion in fresh water at 35°C for 28 days with the exception of 2.4.4(k).

Table 14.2.4 Fibre orientations in reinforced test specimens

Type of reinforcement	Test orientations
Unidirectional	0°
Chopped strand mat Gun roving	any direction
Woven roving Woven cloth Composite roving	0° and 90°
± 45° parallel plied roving Triaxial plied roving Quadriaxial plied roving	0°, 45°, 90° and –45°

2.5 Reinforced thermoplastic polymers

2.5.1 Thermoplastic polymers intended for use with reinforcements are to be tested in accordance with 2.2.1 to 2.2.3.

2.5.2 A laminate is to be prepared using the polymer and an approved reinforcement in accordance with a manufacturing specification. The laminate is to be tested in accordance with the appropriate requirements of 2.4.4. Testing may be confined to one direction only.

2.6 Reinforced thermosetting resins

2.6.1 Thermosetting resins intended for use with reinforcements are to be tested in accordance with 2.3.1 to 2.3.4.

2.6.2 No further tests are required for gel coat resins.

2.6.3 For laminating resins, a laminate is to be prepared using the resin and an approved reinforcement as follows:
(a) For polyester resins, chopped strand mat.
(b) For epoxide resins, a balanced woven roving.
(c) For phenolic resins, a balanced woven material.

2.6.4 The laminate is to be tested in accordance with procedures outlined in MQPS Book K procedure 14-1 and 2.4.4 in one fibre direction only.

2.7 Core materials

2.7.1 **General requirements**. The following data is to be provided for each type of core material:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.

2.7.2 Manufacturers are required to provide a full application procedure for use of the product.

2.8 Specific requirements for end-grain balsa

2.8.1 The supplier is to provide a signed statement that the balsa (ochroma lozopus) is cut to end-grain, is of good quality, being free from unsound or loose knots, holes, splits, rot, pith and corcho, and that it has been treated against fungal and insect attack, shortly after felling, followed by homogenisation, sterilisation and kiln drying to an average moisture content of no more than 12 per cent.

2.8.2 The following tests are to be carried out on the virgin material, both parallel to and perpendicular to the grain:
(a) Compressive strength (stress at maximum load).
(b) Compressive modulus of elasticity.
(c) Tensile strength (stress at maximum load).
The density of the virgin material is also to be tested.

2.8.3 Where the balsa is mounted on a carrier material (e.g. scrim), any adhesive used is to be of a type compatible with the proposed resin system.

2.8.4 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9 Specific requirements for rigid foams (PVC, Polyurethane and other types)

2.9.1 The foam is to be of the closed cell type and compatible with the proposed resin system (e.g., polyester, epoxide, etc.).

2.9.2 Foams are to be of uniform cell structure.

2.9.3 Data is to be provided on the dimensional stability of the foam by measurement of the shrinkage.

2.9.4 The following test data is to be submitted for each type of foam:
(a) Density.
(b) Tensile strength (stress at maximum load).
(c) Tensile modulus of elasticity.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus of elasticity.

2.9.5 Core shear properties are to be determined according to the requirements of 3.8.1.

2.9.6 Additionally, the compressive properties (*see* 2.9.4(d) and (e)) are to be determined at a minimum of five points over the temperature range ambient to maximum recommended service or 70°C, whichever is the greater.

2.10 Synthetic felt type materials with or without microspheres

2.10.1 For materials of this type, the following data is required in addition to the requirements of 2.7.1:
(a) Fibre type.
(b) Width.
(c) Width of finished material.
(d) Weight per unit area of the manufactured material.
(e) Weight per linear metre of the manufactured material.
(f) Compatibility.
(g) Details of the method of combining.

2.10.2 A laminate of the material is to be prepared using a suitable approved resin under conditions recommended by the manufacturer.

2.10.3 The following properties are to be determined:
(a) Tensile strength (stress at maximum load).
(b) Tensile strain at break.
(c) Modulus of elasticity in tension or secant modulus at 0,25 per cent and 0,5 per cent strain.
(d) Compressive strength (stress at maximum load).
(e) Compressive modulus.
(f) Flexural strength (stress at maximum load).
(g) Modulus of elasticity in flexure.
(h) Fibre content.
(j) Water absorption.

2.10.4 In the case of anisotropic materials (e.g., where combined with other reinforcements) the tests listed in 2.10.3 are to be conducted in the 0°, 90° directions and in any other reinforcement direction.

2.10.5 Additionally, the tests listed in 2.10.3 are to be repeated after immersion in fresh water at 35°C for 28 days. For anisotropic materials, the requirement is for this test to be carried out in one direction only.

2.10.6 The shear properties (of the resin filled system) are to be determined according to 3.8.1.

2.11 Machinery chocking compounds (resin chocks)

2.11.1 Thermosetting materials for filling the space between the base of machinery and its foundation where the maintenance of accurate alignment is necessary are to be approved by LR before use.

2.11.2 Approval will be considered by LR for use under the following service conditions:
- Loading of 3,5 N/mm^2 (max) for a temperature not exceeding 60°C.
- Loading of 2,5 N/mm^2 (max) for a temperature not exceeding 80°C.
- Other loading conditions.

2.11.3 The exotherm temperature, defined as the maximum temperature achieved by the reacting resin under conditions equivalent to those of intended use, is to be determined according to a procedure approved by LR.

2.11.4 The following properties are to be determined on chock material cured at the measured exotherm temperature:
(a) The impact resistance (Izod).
(b) Hardness.
(c) Compressive strength (stress at maximum load) and modulus of elasticity.
(d) Water absorption.
(e) Oil absorption.
(f) Heat deflection temperature.
(g) Compressive creep is to be measured according to 3.9.4.
(h) Curing linear shrinkage.
(j) Flammability.

2.11.5 The chocking compound approval is contingent on the material achieving the minimum exotherm value as specified when used on an installation under practical conditions.

2.11.6 Where the resin chock is to be used for installation of sterntubes and sternbushes in addition to the requirements of 2.11.4, the tensile strength and modulus of elasticity in tension are to be measured.

2.11.7 The manufacturer's installation procedure is required to be documented and is to be to the satisfaction of LR.

2.12 Rudder and pintle bearings

2.12.1 Materials used for rudder and pintle bearings are to be approved by LR before use.

2.12.2 Initial approval is to be based on a review of the following physical properties of the material:
(a) Compressive strength (stress at maximum load) and modulus of elasticity.
(b) Tensile strength (stress at maximum load) and modulus of elasticity.
(c) Shear strength (stress at maximum load).
(d) Impact strength.
(e) Swelling in oil and in water.
(f) Hardness.

2.12.3 Additionally, friction data is to be provided under both wet and dry conditions.

2.12.4 Furthermore, the installation instructions (especially recommended clearances) are to be reviewed by LR prior to provisional approval being given.

2.12.5 If the above data is satisfactory, the material will be provisionally approved until sufficient service experience has been gained.

2.13 Sterntube bearings

2.13.1 Materials used for sterntube bearings are to be approved by LR before use.

2.13.2 Approval is to be based on a review of the physical properties as given by 2.12.2.

2.13.3 Friction data is to be provided under the lubrication system(s) proposed for the material(s).

2.14 Plywoods

2.14.1 All plywoods are to be approved to BS 1088 or equivalent National or International Standard in accordance with LR's Type Approval Procedure.

2.14.2 For structural applications in the marine environment, a minimum timber rating of moderate durability according to BS 1088 is required.

2.14.3 Enhancement of durability by use of preservatives is permitted, subject to each veneer layer being treated with a recognised preservative.

2.14.4 Where Okoume, as specified by BS 1088 is involved, (i.e. non-durable timber classification) this may only be used for marine structures subject to the specific application being acceptable to LR.

2.15 Adhesive and sealant materials

2.15.1 Materials of these types are to be accepted by LR before use.

2.15.2 The requirements for acceptance are dependent on the nature of the application.

2.15.3 In the first instance, the manufacturer is to submit full details of the product, procedure for method of use (including surface preparation) and the intended application. After review of these details, LR will provide a specific test schedule for confirmation of the material's properties.

2.15.4 Any acceptance granted will be limited to specific applications and will be contingent on the instructions for use being adhered to.

2.16 Repair compounds

2.16.1 Materials used for repairs are to be accepted by LR before use.

2.16.2 For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.

2.16.3 Dependent on the proposed uses, LR may require testing in accordance with a specified test programme.

2.16.4 Materials will not be accepted for the following uses unless specific evidence of their suitability is provided:
(a) Any component in rubbing contact.
(b) Any component subject to dynamic cyclic loading.
(c) Any pressure part in contact with gas or vapour.
(d) Any pressure part in contact with liquid above 3,5 bar.
(e) Any component where operating temperature exceeds 90°C.

All uses of materials of these types are subject to the discretion of the Surveyor.

■ *Section 3* Testing procedures

3.1 General

3.1.1 This Section gives details of the test methods to be used for base materials and on finished plastics products such as fibre reinforced plastics (FRP) piping and any testing required in the construction of composite vessels.

3.1.2 In general, testing is to be carried out by a competent independent test house which, at the discretion of LR, may or may not require witnessing by the Surveyor.

3.1.3 Alternatively, testing may be carried out by the manufacturer subject to these tests being witnessed by the Surveyor.

3.1.4 All testing is to be carried out by competent personnel.

3.1.5 Unless specified otherwise, testing is to be carried out in accordance with a recognised ISO Standard, where one exists, and all test programmes are to have written procedures.

3.1.6 Alternatively, testing may be carried out in accordance with a National Standard provided that it conforms closely to an appropriate ISO standard and subject to prior agreement with the Surveyor.

3.1.7 Mechanical properties are to be established using suitable testing machines of approved types. The machines and other test equipment are to be maintained in a satisfactory and accurate condition and are to be recalibrated at approximately annual intervals. Calibration is to be undertaken by a nationally recognised authority or other organisation of standing and is to be to the satisfaction of the Surveyor. A record of all calibrations is to be kept available in the test house. The accuracy of test machines is to be within ±one per cent.

3.2 Preparation of test samples

3.2.1 Thermoplastic samples are to be prepared in accordance with the manufacturer's recommendations for moulding. For finished products, samples are to be taken from the product during production in accordance with the manufacturer's quality plan, but where this is impractical, separate test samples are to be prepared in a manner identical with that of the product.

3.2.2 Samples of thermosetting resins are to be prepared using the curing system recommended by the manufacturer and identical with that used for the finished product.

3.2.3 The post curing conditions for samples of thermosetting resins are to be as recommended by the manufacturer and identical with those used for the finished product. Where the samples are made for the general approval of a resin, the post curing conditions are to be those in which the resin is intended to be used.

3.2.4 Where curing of the product is intended to take place at room temperature, the sample is to be allowed to cure at room temperature (18 to 21°C) for 24 hours followed by a post-cure at 40°C for 16 hours.

3.2.5 Where a reinforcement is to be used, the ratio of reinforcement to resin or polymer is to be nominally the same as that of the finished product or in accordance with Table 14.2.2 or 14.2.3.

3.2.6 Where laminates are prepared specifically for approval test purposes, the reinforcement is to be laid parallel plied.

3.3 Preparation of test specimens

3.3.1 The test specimen is to be prepared in accordance with the appropriate ISO standard and the requirements of this Section.

3.3.2 Precautions are to be taken during machining to ensure that the temperature rise in the specimen is kept to a minimum.

3.4 Testing

3.4.1 Strain measurement is to be made by the use of a suitable extensometer or strain gauge.

3.4.2 The rate of strain is to be in accordance with the appropriate ISO standard.

3.4.3 The number of test specimens from each sample to be tested is to be in accordance with the ISO standard. For mechanical testing this is five.

3.5 Discarding of test specimens

3.5.1 If a test specimen fails because of faulty preparation or incorrect operation of the testing machine, it is to be discarded and replaced by a new specimen.

3.5.2 In addition, if the deviation of one result in a group of five exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested, *see* 1.8.1 and 1.8.2.

3.6 Reporting of results

3.6.1 All load/displacement graphs and tabulated results are to be reported, including mean values and the calculated standard deviation.

3.6.2 Additionally, full details of the sample and specimen preparation are to be provided including (where applicable):
(a) Catalyst/accelerator or curing agent types and mix ratio.
(b) Weights of resins, and/or reinforcements used.
(c) Casting/laminate dimensions.
(d) Number of layers of reinforcement used.
(e) Curing/post-curing conditions.

3.7 Tests for specific materials

3.7.1 The data requirements in 2.2 and 2.3 for thermoplastic or thermosetting resins or polymers are to be determined in accordance with suitable National or International Standards.

3.7.2 Recognised Standards to which specimens of unreinforced thermoplastic resins are to be tested are listed in Table 14.3.1.

3.7.3 Test standards for unreinforced cast thermosetting resins are given in Table 14.3.2.

3.7.4 The Standards to which laminate specimens of any type are to be tested are listed in Table 14.3.3.

Table 14.3.1 Tests for unreinforced thermoplastic resins

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed – as for ductile materials

NOTES
1. Water absorption – result to be expressed as milligrams.
2. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

Table 14.3.2 Tests on unreinforced cast thermoset resin specimens

Test	Standard	
Tensile properties	ISO 527-2:1993	Test speed = 5 mm/min Specimen 1A or 1B
Flexural properties	ISO 178:2001	Test speed = $\frac{\text{Thickness}}{2}$ mm/min
Water absorption	ISO 62:2008	Method 1
Temperature of deflection under load	ISO 75-2:2004	Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-2:1993 – tensile properties are to be measured using extensometry.

3.8 Structural core materials

3.8.1 Initially, the core shear strength and modulus are to be determined by ISO 1922:2001 or ASTM C273/C273M. Test sandwich panels are then to be prepared and subjected to four-point flexural tests to determine the apparent shear properties according to ASTM C393/C393M:06 (short beam) at two representative thicknesses (i.e., 15 mm and 30 mm). Testing is to be carried out at ambient temperature and at 70°C. The following requirements are to be observed:

(a) Each skin is to be identical and have a thickness not greater than 21 per cent of the nominal core thickness. For hand laid constructions, each skin is to comprise a lightweight chopped strand mat reinforcement (300 g/m^2) consolidated at a glass content, by weight, of 0,3 against

Table 14.3.3 Tests on laminate specimens

Test	Standard	
Tensile properties	ISO 527-4:1997	Test speed = 2 mm/min Specimens Types II or III
Flexural properties	ISO 14125:1998	Test speed = $\frac{\text{Thickness}}{2}$ mm/min Method A
Compressive properties	ISO 604:2002	Test speed = 1 mm/min
Interlaminar shear	ISO 14130:1997	
Water absorption	ISO 62:2008	Method 1
Glass content	ISO 1172:1996	

NOTES
1. ISO 62:2008 – where resins are intended for use under ambient conditions to avoid additional post-curing, the requirement in ISO 62:2008 for pre-drying the test specimen at 50°C is to be omitted. The test result is to be expressed as mg of water.
2. ISO 527-4:1997 – tensile properties are to be measured using extensometry.
3. Tensile modulus values are to be determined using an extensometer which may be removed for strain to failure.

the core, plus the required number of woven reinforcements consolidated, using an isophthalic polyester resin, to give a minimum glass content, by weight, of 0,5.

(b) The method of construction of the sandwich laminate is to reflect the core material manufacturer's instructions for use, i.e., application of bonding paste, surface primer or any other recommended system.

(c) Where vacuum bagging techniques or equivalent systems are used, these will be subject to individual consideration.

(d) All resins and reinforcements are to hold current LR approval.

(e) Curing conditions are to be in accordance with 3.2.3 and 3.2.4.

(f) The dimensions of the test samples should be based on the requirements of ASTM C393 Paragraph 5.1, and the ratio parameters as indicated in ASTM C393 Paragraph 5.2, using a proportional limit stress (F) for the woven roving skins of 130 N/mm^2 and a span (a_2) of not less than 400 mm.

3.8.2 For each type of test sample, the following data are to be reported, together with the submission of a representative test sample showing the mode of failure for each density of core material:

(a) Skin and core thickness, and core type and density.
(b) Resin/catalyst/accelerator ratio.
(c) Skin construction, including types and weight of reinforcements, resin(s), etc.
(d) Details of production method and curing conditions (temperature and times).
(e) Where additional preparation of the foam is involved, for example the use of primers or bonding pastes, full details are to be provided.

(f) Actual span between base supports for each type of test sample.

3.8.3 The following requirements apply to end-grain balsa:
(a) The data requirements of 2.7.1 are to be provided, where applicable, according to suitable National or International Standards.
(b) The balsa is to be tested according to the requirements of 3.8.1.
(c) The test methods for balsa are given in Table 14.3.4.

Table 14.3.4 Tests on end-grain balsa

Test	Standard
Density	ISO 845:2006
Tensile properties	ASTM C297/C297M:04 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Compressive properties	ISO 844:2007 Test speed = $\frac{\text{Thickness}}{10}$ mm/min
Shear properties	ISO 1922:2001 Test speed = 1mm/min

3.8.4 The following requirements apply to rigid foams:
(a) The data requirements of 2.7.1 are to be provided in accordance with a suitable National or International Standard.
(b) The foam is to be tested according to the requirements of 3.8.1.
(c) The test methods for rigid foams are to be in accordance with Table 14.3.4.

3.8.5 The following requirements apply to synthetic felt type materials:
(a) The data requirements of 2.10.1 are to be provided according to suitable National or International Standards.
(b) The material is to be tested according to the requirements of 3.8.1, with the following modifications:
  (i) The core of the laminate test sandwich panel is to be prepared with a fibre content as recommended by the manufacturer.
  (ii) The felt fibre/resin ratio is to be stated.
  (iii) The required test thicknesses of the cores are to be changed from 30 mm and 15 mm to 12 mm and 6 mm respectively.
(c) The prepared laminate of the base material is to be of minimum thickness 3,5 mm with a minimum of three layers.
(d) The specified tests on the laminate (*see* 2.10.3) are to be conducted according to the requirements of Table 14.3.3.

3.9 Machinery chocking compounds

3.9.1 Test samples of the cured chock resin are to be prepared under ambient conditions and then post-cured at the exotherm temperature as determined in 2.11.3.

3.9.2 The specified properties are to be determined as required by Table 14.3.5.

Table 14.3.5 Tests for machinery chocking compounds

Test	Standard
Izod Impact Resistance	ISO 180-2000 Unnotched
Barcol hardness	ASTM D2583-07 or BS 2782 part 10 Method 1001
Compressive strength	ISO 604:2002 Test speed = 1 mm/min
Water absorption	ISO 62:2008 Method 1 25 mm x 20 mm cylinder (to constant weight)
Oil absorption (light machine)	ISO 175:1999 25 mm x 20 mm cylinder (to constant weight)
Temperature of deflection under load	ISO 75-2 Method A

3.9.3 The percentage linear shrinkage of cured material is to be measured.

3.9.4 Creep is to be measured according to the following method:
(a) A 25 mm x 20 mm diameter parallel faced cylinder is to be pre-loaded against a steel base at 2,5 N/mm^2 or 3,5 N/mm^2, or at the specified higher loading condition, at ambient temperature for 16 hours.
(b) The temperature is to be increased at the rate of 8°C per hour until the service temperature (60°C or 80°C) is reached.
(c) During this time, the creep of the cylinder is to be measured at 15 minute intervals.
(d) The temperature and loading are to be maintained for a minimum of 100 days measuring the creep at intervals of 24 hours.
(e) A plot of creep in mm (linear scale) against time (log scale), together with full experimental details, is to be provided for review by LR.

3.10 Rudder and pintle bearings

3.10.1 All mechanical properties as required by 2.12 are to be measured according to suitable National or International Standards.

3.10.2 Frictional properties are to be determined according to a method agreed with LR.

3.11 Sterntube bearings

3.11.1 The requirements for sterntube bearings are as defined in 2.13.

■ *Section 4*
Plastics pipes and fittings

4.1 Scope

4.1.1 This Section gives the general requirements for plastics pipes and fittings, with or without reinforcement, intended for use in the services listed in the relevant Rules dealing with design and construction. Hoses and mechanical couplings are not covered by these requirements.

4.1.2 Pipes and fittings intended for application in Class I, Class II and Class III systems for which there are Rule requirements, are to be manufactured in accordance with the requirements of Section 1 and this Section.

4.1.3 As an alternative to 4.1.2, plastics pipes and fittings which comply with National or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to the requirements of this Section or, alternatively, are approved for a specific application. The survey and certification are however to be carried out in accordance with the requirements of this Section.

4.2 Design requirements

4.2.1 The requirements for design approval are detailed in the relevant Rules.

4.2.2 The design submission is to include a materials list with confirmation that the materials listed have properties and characteristics conforming with those values used in the design submission. As a minimum, the details given should include the following:
(a) Resin.
(b) Accelerator (type and concentration).
(c) Catalyst or curing agent (type and concentration).
(d) Reinforcement.
(e) Cure/post-cure conditions.
(f) Resin/reinforcement ratio.
(g) Wind angle (or lay-up sequence) and orientation.
(h) Dimensions and tolerances.
This submission is to include similar details for the fittings together with a description of the method of attachment of the fittings to the pipes.

4.2.3 Any alteration of the component materials or manufacturing operations from those used in the design submission will necessitate a completely new submission.

4.2.4 If the piping manufacturer anticipates the possible use of alternative materials, these should be listed in the design submission. Proof that the modified product will meet the specified requirements will be needed prior to its use.

4.3 Manufacture

4.3.1 Plastics pipes and fittings intended for use in Class I, Class II and Class III systems are to be manufactured at facilities approved by LR, using materials approved by LR.

4.3.2 A Manufacturing Specification is to be submitted. This is to contain details of the following:
(a) All constituent materials.
(b) Manufacturing procedures such as lay-up sequence or wind angle, the ratios of curing agent to resin and reinforcement to resin, the laminate thickness, the mandrel dwell time (initial cure) and the cure and post-cure conditions.
(c) Quality control procedures including details and frequency of tests on the incoming materials, tests made during production and on the finished piping.
(d) Acceptance standards and tolerances, including all dimensions.
(e) Procedures for cosmetic repair.
(f) System for traceability of the finished piping to the batches of raw materials.
(g) Method of bonding pipes and fittings.

4.3.3 Details of all raw materials are to be submitted for approval and are to be in accordance with the Manufacturing Specification and the design submission.

4.3.4 All batches of raw materials are to be provided with unique identifications by their manufacturers.

4.3.5 No batch of material is to be used later than its date of expiry.

4.3.6 The piping manufacturer is to ensure that all batches of materials are used sequentially.

4.3.7 The piping manufacturer is to maintain records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the Manufacturing Specification.

4.3.8 Records are to be kept of the wind angle and/or the orientation of the reinforcement.

4.3.9 The piping manufacturer is to ensure that each item of piping is traceable to the batch or batches of material used in its manufacture. The unique identifications referred to in 4.3.4 are to be included on all documents.

4.3.10 The curing oven is to be suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

4.3.11 The temperature of the pipe or fitting is to be controlled and recorded by the attachment of suitably placed thermocouples.

4.4 Quality assurance

4.4.1 The piping manufacturer is to have a quality assurance system approved to ISO 9001 or equivalent. This system should ensure that the pipes and fittings are produced with uniform and consistent mechanical and physical properties in accordance with acceptable standards.

4.5 Dimensional tolerances

4.5.1 Dimensions and tolerances are to conform to the Manufacturing Specification.

4.5.2 The wall thicknesses of the pipes are to be measured at intervals around the circumference and along the length in accordance with an appropriate National Standard. The thicknesses are to accord with the Manufacturing Specification.

4.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer. Occasional checking by the Surveyor does not absolve the manufacturer from this responsibility.

4.6 Composition

4.6.1 The composition of the pipes and fittings is to be in accordance with the Manufacturing Specification.

4.6.2 Where alternative materials are used (*see* 4.2.4), the manufacturer is to demonstrate to the Surveyor's satisfaction, and prior to their introduction, their suitability with respect to the performance of the piping. Otherwise, full testing as specified in 4.7 will be required.

4.7 Testing

4.7.1 For thermoplastic pipes, the polymer manufacturer is to make the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

4.7.2 The values obtained are to be certified by the polymer manufacturer.

4.7.3 For reinforced thermoset pipes,the resin manufacturer is to determine, on samples taken from each batch, at least the following:
(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.
(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

4.7.4 The values obtained are to comply with the requirements of the Manufacturing Specification.

4.7.5 Where the resin manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 4.7.1 to 4.7.3 as appropriate. The mixed batch is then to be given a unique batch number.

4.7.6 The polymer or resin manufacturer is to demonstrate that each batch of polymer or resin satisfies the requirement for temperature of deflection under load and this is not to be less than 80°C.

4.7.7 These measurements should be repeated on each batch by the piping manufacturer. Where this is not done, LR may require that the tests be made on a random basis by an independent laboratory.

4.7.8 The piping manufacturer is to confirm, by means of tests on at least one batch in twenty, that the temperature of deflection under load exceeds the specified minimum under manufacturing conditions.

4.7.9 Where reinforcements are used, at least the following are to be recorded, where applicable:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

4.7.10 All items in 4.7.9 are to comply with the Manufacturing Specification.

4.7.11 The piping manufacturer is to maintain accurate records of resin and glass usage and is to calculate the resin/glass ratio on an ongoing basis.

4.7.12 During manufacture of the piping, apart from the requirements of 4.7.5, 4.7.6 and 4.7.8, tests are to be carried out on the constituents and final product in accordance with Table 14.4.1.

4.7.13 The standards of acceptance are those listed in the Manufacturing Specification approved by LR.

4.7.14 At the Surveyor's discretion, sections of pipe are to be subjected to hydraulic bursting tests and/or measurements of axial strength.

4.7.15 If the batch of resin or polymer, or the curing agent, or their ratio is changed during manufacture of a batch of pipes, at least two additional measurements of the gel time are to be carried out during each shift.

Table 14.4.1 Testing during manufacture of pipes

Component/ operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time Rate of consumption	Two per shift Continuous
Reinforcement	Quality Wind angle Rate of consumption	Continuous Continuous Continuous
Resin/ reinforcement	Ratio	Continuous
Pipe	Post-cure: temperature of the pipe in oven	Continuous
	Cure level	At least eight per length
	Dimensions	Each length
	Hydraulic pressure test	Each length
	Electrical resistance	Each length (*see* Note)
	Hydraulic bursting test	At Surveyor's discretion
	Axial strength	At Surveyor's discretion

NOTE
Measurements of electrical resistance are only required on piping where the operating conditions given in Pt 5, Ch 12,5.2.4 of the *Rules and Regulations of the Classification of Ships* apply.

4.8 Visual examination

4.8.1 All pipes and fittings are to be visually examined and are to be free from surface defects and blemishes.

4.8.2 The pipes are to be reasonably straight and the cut ends are to be square to the axis of the pipe.

4.9 Hydraulic test

4.9.1 Each length of pipe is to be tested at a hydrostatic pressure not less than 1,5 times the rated pressure of the pipe.

4.9.2 The test pressure is to be maintained for sufficient time to permit proof and inspection. Unless otherwise agreed, the manufacturer's certificate of satisfactory hydraulic test, endorsed by the Surveyor, will be accepted.

4.10 Repair procedure

4.10.1 Repairs are not allowed, with the exception of minor cosmetic blemishes as detailed in 1.10.1.

4.10.2 A repair procedure for these minor blemishes is to be included in the Manufacturing Specification.

4.11 Identification

4.11.1 All piping is to be identified in such a manner that traceability to all the component materials used in its manufacture is ensured. The Surveyor is to be given full facilities for tracing the material when required.

4.11.2 Pipes and fittings are to be permanently marked by the manufacturer by moulding, hot stamping or by any other suitable method, such as printing, in accordance with 1.11. The markings are to include:
(a) Identification number, *see* 4.11.1.
(b) LR or Lloyd's Register, and the abbreviated name of LR's local office.
(c) Manufacturer's name or trademark.
(d) Pressure rating.
(e) Design standard.
(f) Material system with which the piping is made.
(g) Maximum service temperature.

4.12 Certification

4.12.1 The manufacturer is to provide the Surveyor with copies of the test certificates or shipping statements for all material which has been accepted.

4.12.2 Each test certificate is to contain the following particulars:
(a) Purchaser's name and order number.
(b) If known, the contract number for which the piping is intended.
(c) Address to which piping is despatched.
(d) Type and specification of material.
(e) Description and dimensions.
(f) Identification number, *see* 4.11.1.
(g) Test results.

■ *Section 5*
Control of material quality for composite construction

5.1 Scope

5.1.1 This Section gives the general requirements for control of material quality when used in the construction of composite craft.

5.1.2 For composite craft built under the Rules, the survey of materials is to be conducted in accordance with the requirements of Sections 1 to 3 and this Section.

5.2 Design submission

5.2.1 The requirements for design submission are detailed in the appropriate Part of the Rules which includes full information on composite materials.

5.3 Construction

5.3.1 All constructions are to be carried out using materials approved or accepted by LR.

5.3.2 All materials are to be in accordance with the approved construction documentation.

5.3.3 All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.

5.3.4 No batch of material is to be used later than its date of expiry.

5.3.5 The Builder is to ensure that all batches of materials are used systematically and sequentially.

5.3.6 The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.

5.3.7 Records are to be kept of the sequence and orientation of the reinforcements.

5.3.8 The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used. The unique identifications required under 1.11.1 are to be included on all relevant quality control documentation.

5.3.9 Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.

5.3.10 The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

5.4 Quality assurance

5.4.1 Where the Builder has a quality assurance system, this is to include the requirements of this Section.

5.5 Dimensional tolerances

5.5.1 Dimensions and tolerances are to conform to the approved construction documentation.

5.5.2 The thicknesses of the laminates are, in general, to be measured at not less than ten points, evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

5.5.3 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.

5.5.4 Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

5.6 Material composition

5.6.1 The materials, prefabricated sections or components used are to be in accordance with the approved construction documentation.

5.6.2 Where alternative materials are used, these are to be of approved or accepted types and the manufacturer is to demonstrate to the Surveyor's satisfaction, prior to their introduction, their suitability with respect to performance, otherwise full testing as appropriate will be required.

5.7 Material testing

5.7.1 Where so required, the material manufacturer is to provide the purchaser with certificates of conformity for each batch of material supplied, indicating the relevant values specified in 5.7.4 to 5.7.8. These values are to comply with those specified by the approved construction documentation.

5.7.2 Where the Builders do not conduct verification testing of the information indicated in 5.7.4 to 5.7.8, they are to ensure that copies of all certificates of conformity (which must indicate the actual tested values) are obtained for all batches of materials received, and maintain accurate records. The Surveyor may at any time select a sample of a material for testing by an independent, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

5.7.3 The following tests are to be carried out, where applicable, on receipt of any material:

(a) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
(b) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
(c) Each batch is to be separately labelled and stored separately.
(d) Each unit, within the batch, is to be labelled with the batch number.
(e) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

5.7.4 For thermosetting resins, reinforced or otherwise, the resin manufacturer is to have determined, on samples taken from each batch, at least the following:

(a) All resins:
  (i) Viscosity.
  (ii) Gel time.
  (iii) Filler content, where applicable.
(b) Polyester and vinylester resins:
  (i) Type (orthophthalic, isophthalic, etc.).
  (ii) Volatiles content.
  (iii) Acid value.

(c) Epoxide resins:
  (i) Free epoxide content.
(d) Phenolic resins:
  (i) Free phenol content.
  (ii) Free formaldehyde content.

5.7.5 For thermoplastics, the polymer manufacturer is to have made the following measurements on samples taken from each batch:
(a) Melting point.
(b) Melt flow index.
(c) Density.
(d) Filler/pigment content, where applicable.
(e) Tensile stress at yield and break.
(f) Tensile strain at yield and break.

5.7.6 Where the resin or polymer manufacturer mixes batches, both the original batches and the mixed batch are to be tested in accordance with 5.7.4 or 5.7.5 as appropriate. The mixed batch is then to be given a unique batch number.

5.7.7 For reinforcements, the material manufacturer is to have recorded, where applicable, the following for each batch of material:
(a) Tex of yarn(s) or roving(s).
(b) Ends per 100 mm in all reinforcement orientations.
(c) Weight per square metre.
(d) Binder/size content.
(e) Stitch type and count.
(f) Type of fibre used.
(g) Surface treatment and/or finish.

5.7.8 For core materials, the following properties are to be recorded by the manufacturer for each batch:
(a) Type of material.
(b) Density.
(c) Description (block, scrim mounted, grooved).
(d) Thickness and tolerance.
(e) Sheet/block dimensions.
(f) Surface treatment.
Together with the following mechanical properties:
In the case of rigid foams:
(g) Compressive strength (stress at maximum load) and modulus of elasticity.
(h) Core shear strength.In the case of end-grain balsa:
(j) Tensile strength (stress at maximum load).
(k) Compressive strength (stress at maximum load) and modulus of elasticity.

5.7.9 During construction, tests are to be carried out on the constituents and final product in accordance with Table 14.5.1.

5.7.10 The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable.

5.7.11 Laminate fibre content is to be determined at the request of the Surveyor, in particular where the thickness measured does not correlate with the specified fibre content, by weight. This will, in general, result in additional reinforcement being required.

5.7.12 If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.

5.8 Visual examination

5.8.1 All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

Table 14.5.1 Testing during construction

Component/operation	Characteristic	Rate of testing
Resin/curing agent/catalyst	Gel time	Two per shift
	Rate of consumption	Continuous
Reinforcement	Quality	Continuous
	Orientation	Continuous
	Rate of consumption	Continuous
Resin/reinforcement	Ratio	Continuous
Construction	Temperature during cure/post cure	Continuous
	Dimensions	Continuous against approved construction documentation
	Cure level (Barcol) against resin manufacturer's specification	At least one per square metre
	Laminate thickness	Continuous against material usage and approved construction documentation (*see also* 5.5.2 to 5.5.4)
	Laminate fibre content	At the Surveyor's request (*see* 5.7.11)

5.9 Repair procedure

5.9.1 Repairs of minor cosmetic blemishes are permitted providing that these are brought to the attention of the Surveyor.

5.9.2 A repair procedure for these minor blemishes is to be included in the agreed quality control procedures.

5.9.3 Structural repairs are subject to individual consideration and full written details must be approved by the plan approval office prior to introduction.

5.10 Material identification

5.10.1 Records of the construction are to be kept in such a manner that traceability of all the component materials used is ensured. The Surveyor is to be given full facilities for tracing the material's origin when required.

5.10.2 Small representative samples of each batch of material are to be retained, these being suitably labelled to ensure traceability.

5.10.3 When so requested by the Surveyor, the Builder is to provide copies of all test data and/or manufacturers' certificates of conformity appertaining to any material used.

5.11 Minimum tested requirements for material approval

5.11.1 This Section provides the minimum property values required of a material for approval or acceptance by LR and are applicable to materials cured under ambient conditions.

5.11.2 **Gel coat resins**. When the cast resin is tested according to the requirements of 2.3, Table 14.5.2 gives the minimum values for the respective properties.

5.11.3 **Laminating resins**. When tested according to the requirements of 2.3 and 2.4, Tables 14.5.3 and 14.5.4 give the minimum properties for the cast resin and chopped strand mat laminate respectively.

5.11.4 When tested to the requirements of 2.4 for reinforcements, Table 14.5.5 gives the minimum properties for laminates.

5.11.5 Alternatively, materials may be approved by use of the actual tested values whereby the approval value shall equal the mean of the tested values minus twice the standard deviation of a minimum of five tested values.

5.12 Closed cell foams for core construction based on PVC or polyurethane

5.12.1 Table 14.5.6 gives minimum values for closed cell forms for core construction based on PVC or polyurethane.

5.12.2 Other types of foam will be subjected to individual consideration. A minimum core shear strength of 0,5 N/mm^2 is to be achieved.

Table 14.5.2 Gel coat resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,5%
Modulus of elasticity in tension	As measured
Flexural strength (stress at maximum load)	80 N/mm^2
Modulus of elasticity in flexure	As measured
Barcol hardness	As measured at full cure
Water absorption	70 mg (max)

Table 14.5.3 Laminating resins, minimum property values

Properties	Minimum value
Tensile strength (stress at maximum load)	40 N/mm^2
Tensile stress at break	40 N/mm^2
Tensile strain at maximum load	2,0%
Modulus of elasticity in tension	As measured
Barcol hardness	As measured at full cure
Temperature of deflection under load	55°C
NOTE These minimum values are for the recommended glass content by weight of 0,3.	

5.13 End-grain balsa

5.13.1 Table 14.5.7 gives the minimum property requirement for end-grain balsa.

5.14 Synthetic chocking compounds

5.14.1 Table 14.5.8 gives the minimum property requirements for synthetic chocking compounds.

5.15 Other materials

5.15.1 All other materials will be subject to special consideration.

Table 14.5.4 Laminating resins, minimum values for properties for CSM laminate at 0,3 glass fraction by weight

Properties	Minimum value
Tensile strength (stress at maximum load)	90 N/mm^2
Secant modulus at 0,25% and 0,5% strain respectively	6,9 kN/mm^2
Compressive strength (stress at maximum load)	125 N/mm^2
Compressive modulus	6,4 kN/mm^2
Flexural strength (stress at maximum load)	160 N/mm^2
Modulus of elasticity in flexure	5,7 kN/mm^2
Apparent interlaminar shear strength (*see* Note)	18 N/mm^2
Fibre content	As measured (0,3)
Water absorption	70 mg (max)

NOTE
Applicable only to the special test for environmental control resins.

Table 14.5.5 Laminates, minimum property requirements

Material type	Property	Value
Chopped strand mat	Tensile strength (stress at maximum load) (N/mm^2)	$200G_c + 30$
	Modulus of elasticity in tension (kN/mm^2)	$15G_c + 2,4$
Bi-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$400G_c - 10$
	Modulus of elasticity in tension (kN/mm^2)	$30G_c - 0,5$
Uni-directional reinforcement	Tensile strength (stress at maximum load) (N/mm^2)	$1800G_c^2 - 1400G_c + 510$
	Modulus of elasticity in tension (kN/mm^2)	$130G_c^2 - 114G_c + 39$
Chopped strand mat	Flexural (stress at maximum load) (N/mm^2)	$502G_c^2 + 114,6$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,7$
All	Flexural strength (stress at maximum load) (N/mm^2)	$502G_c^2 + 106,8$
	Modulus of elasticity in flexure (kN/mm^2)	$33,4G_c^2 + 2,2$
	Compressive strength (stress at maximum load) (N/mm^2)	$150G_c + 72$
	Compressive modulus (kN/mm^2)	$40G_c - 6$
	Interlaminar shear strength (N/mm^2)	$22 - 13,5G_c$ (min 15)
	Water absorption (mg)	70 (maximum)
	Glass content (% by weight)	As measured

NOTES
1. After water immersion, the values shall be a minimum of 75% of the above.
2. Where materials have reinforcement in more than two directions, the requirement will be subject to individual consideration dependent on the construction.
3. G_c = glass fraction by weight.

Table 14.5.6 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

Material	Apparent density kg/m^3	Strength (stress at maximum load) (N/mm^2)			Modulus of elasticity (N/mm^2)	
		Tensile	Compressive	Shear	Compressive	Shear
Polyurethane	96	0,85	0,60	0,50	17,20	8,50
Polyvinylchloride	60					

Table 14.5.7 Minimum characteristics and mechanical properties of end-grain balsa

Apparent density (kg/m^3)	Strength (stress at maximum load) (N/mm^2)					Compressive modulus of elasticity (N/mm^2)		Shear modulus of elasticity (N/mm^2)
	Compressive		Tensile		Shear	Direction of stress		
	Direction of stress							
	Parallel to grain	Perpendicular to grain	Parallel to grain	Perpendicular to grain		Parallel to grain	Perpendicular to grain	
96	5,0	0,35	9,00	0,44	1,10	2300	35,2	105
144	10,6	0,57	14,6	0,70	1,64	3900	67,8	129
176	12,8	0,68	20,5	0,80	2,00	5300	89,6	145

Table 14.5.8 Minimum characteristics and mechanical properties of synthetic chocking compound

Properties	Minimum value
Izod Impact Resistance	0,8 J
Barcol hardness	40
Compression	100 MPa
Water absorption	0,05%
Oil absorption (light machine)	0,05%
Creep	< 0,2%

NOTES
1. Izod, barcol, compression, and water and oil absorption tests to be performed on samples cured/post-cured to the same condition as the samples for the final creep tests.
2. Minimum creep value to be attained for a stabilised sample after 1000 hours.

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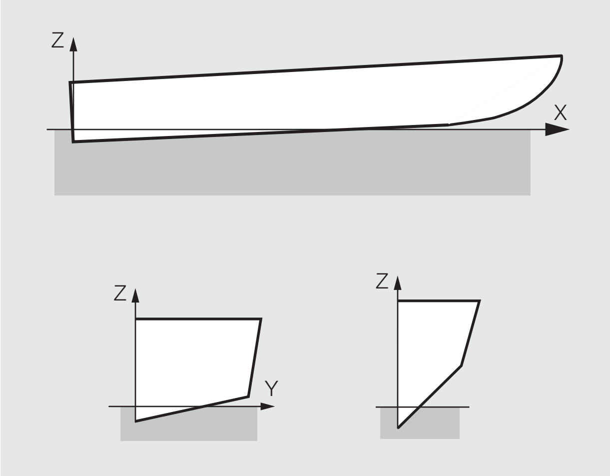
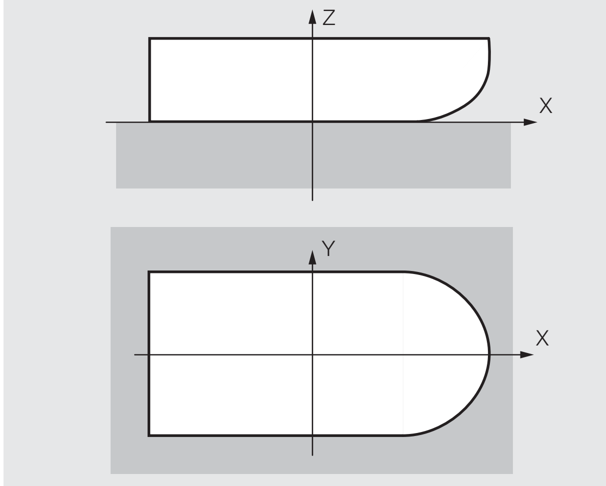
LIFE MATTERS

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

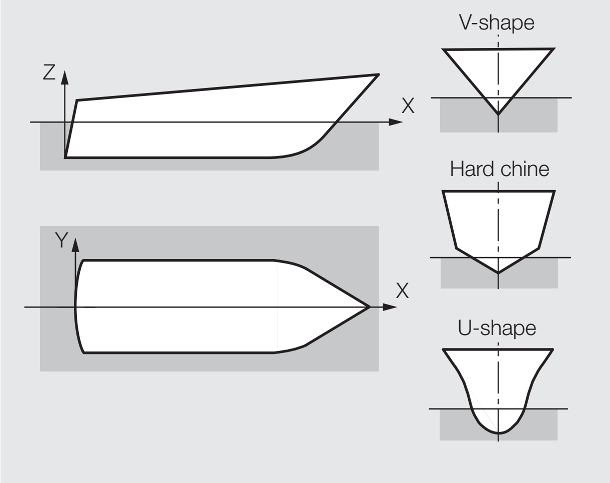
PLANING CRAFT



HOVERCRAFT



DISPLACEMENT CRAFT



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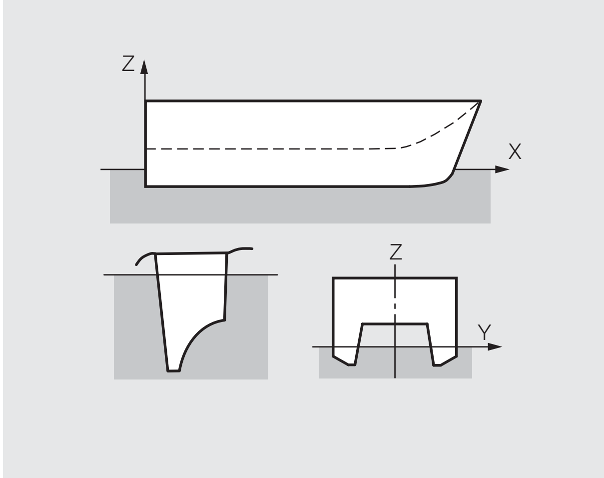

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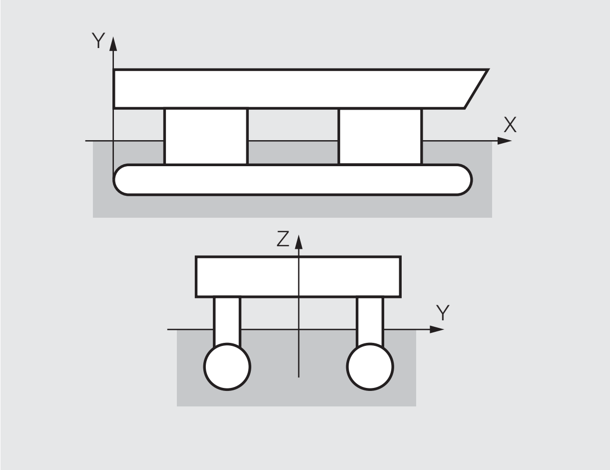
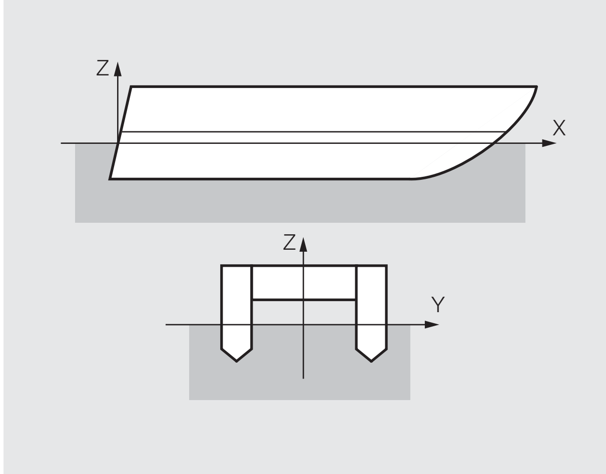
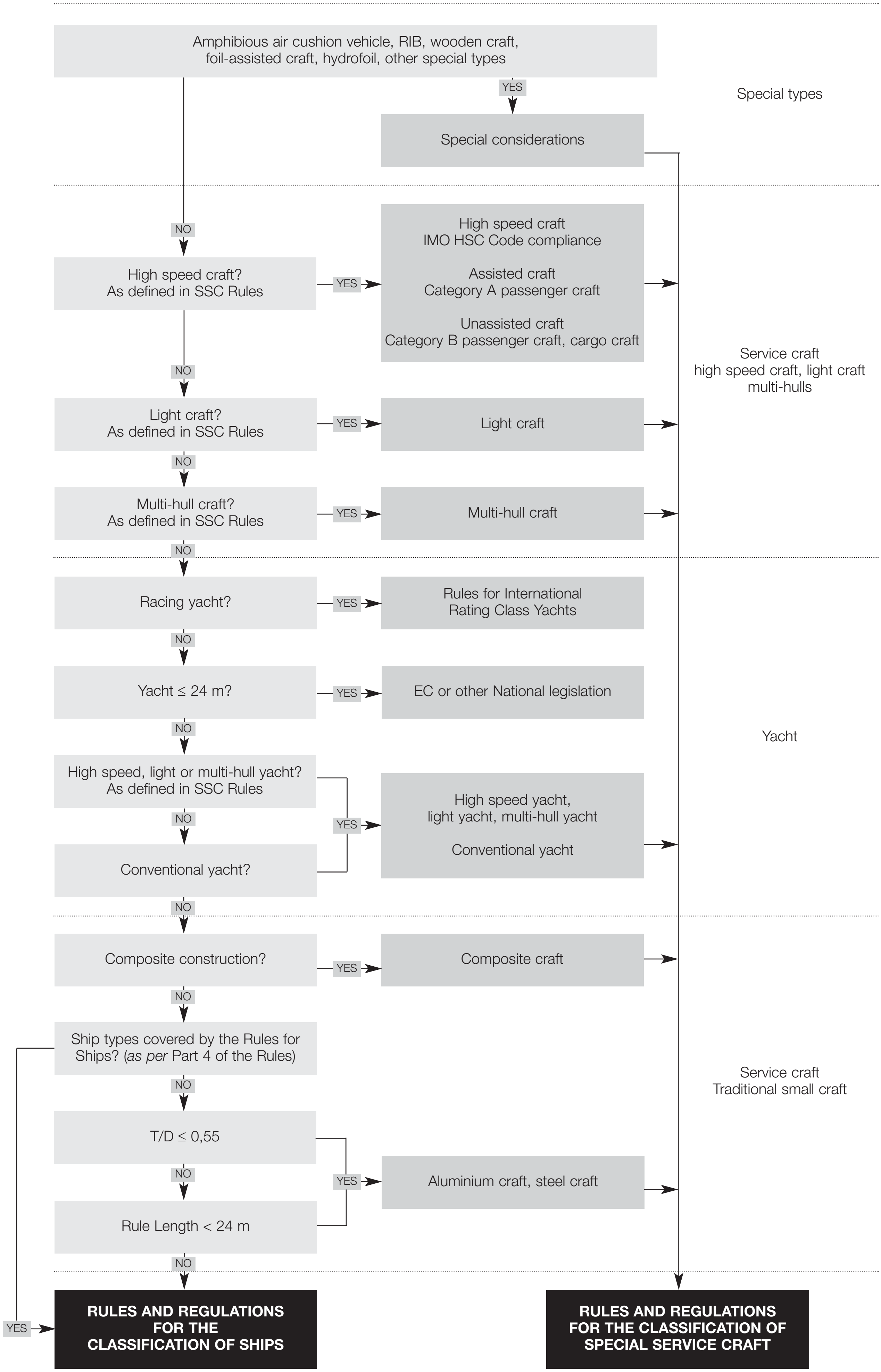


CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



Rules and Regulations for the Classification of Special Service Craft

Volume 3

Part 3

General Requirements and Constructional Arrangements

July 2012

LIFE MATTERS

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Section 1
Rules application

1.1 General

1.1.1 The Rules apply to sea-going motor, sailing and auxiliary craft of normal form, proportions and speed, generally not exceeding a Rule length, L_R of 150 m.

1.2 Exceptions

1.2.1 Craft of unusual form, proportions or speed, or intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that craft will be properly loaded and handled; they do not, unless it is stated or implied in the class notation, provide for special distributions or concentrations of loading other than those included in the approved Loading Manual. The Committee may require additional strengthening to be fitted in any craft which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

Section 2
Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for craft having novel design features, as defined in 1.2, or may be submitted in support of alternative arrangements and scantlings. Lloyd's Register (hereinafter referred to as 'LR') may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: Schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the Builder.

2.3 Global hull strength

2.3.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding that specified in Chapter 6, of Parts 6, 7 and 8, for steel, aluminium alloy and composite respectively, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

2.3.2 Where the Rule length, L_R, does not exceed that indicated in 2.3.1, longitudinal strength calculations may be required at LR's discretion, dependent upon craft proportions, the proposed loading, structural configuration and material of construction.

Section 3
Equivalents

3.1 Alternative arrangements and scantlings

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements and scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures other than those available within the LR *Software Guide* are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:
- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses;
- factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:
(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.
(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

3.1.7 Alternative arrangements which are in accordance with the requirements of a National Authority may be accepted as equivalent to the requirements of this Part of the Rules.

Section 4
National and International Regulations

4.1 International Conventions

4.1.1 The Committee, when authorised, will act on behalf of Governments and, if requested, LR will certify compliance in respect of National and International statutory safety and other requirements for passenger and cargo craft.

4.1.2 In satisfying the Load Line Convention, the general structural strength of the craft is required to be sufficient for the draught corresponding to the freeboards to be assigned. Craft built and maintained in accordance with LR's Rules and Regulations possess adequate strength to satisfy the Load Line Convention. However, some National Authorities may, in addition, require to be supplied with calculations of bending moments and shear forces for certain conditions of loading.

4.2 International Association of Classification Societies (IACS)

4.2.1 Where applicable, the Rules take into account unified requirements and interpretations established by IACS.

4.3 International Maritime Organization (IMO)

4.3.1 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside the scope of classification as defined in these Rules and Regulations.

Section 5
Information required

5.1 General

5.1.1 The categories and lists of information required are given in 5.2.

5.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

5.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

5.1.4 Additional requirements for individual craft types are given in subsequent Chapters.

5.2 Submission of plans and data

5.2.1 Plans and data required to be submitted are indicated in Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively, as appropriate.

5.2.2 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8.2, plans and information covering the following items are to be submitted:
- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the craft afloat.
- Details showing how stern bush clearances are to be measured with the craft afloat.
- Details of high resistant paint, for information only.

5.3 Standard designs

5.3.1 Where a craft is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

5.3.2 Where the craft is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc., is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

5.3.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

5.4 Plans and data to be supplied to the craft

5.4.1 To facilitate the ordering of materials for repairs, plans are to be carried in the craft indicating the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

5.4.2 Similar information is to be provided when aluminium alloy, fibre composite or other materials are used in the hull construction.

5.4.3 A copy of the final Loading Manual, (where applicable) when approved, and details of the loadings applicable to approved decks, hatch covers and inner bottom are to be placed on board the craft.

5.4.4 Details of any corrosion control system fitted are to be placed on board the craft.

5.4.5 Copies of main scantling plans are to be placed on board.

5.4.6 Where an ***IWS** (In-water Survey) notation is to be assigned, approved plans and information covering the items detailed in 5.2.2 are to be placed on board.

5.5 Fire protection, detection and extinction

5.5.1 For information and plans required, *see* Part 17.

■ *Section 6* Definitions

6.1 General

6.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

6.2 Principal particulars

6.2.1 **Rule length**, L_R, is the distance, in metres, on the summer load waterline from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on the summer load waterline. In craft without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on the summer load waterline. In craft with unusual stem or stern arrangements the Rule length, L_R, will be specially considered.

6.2.2 **Length between perpendiculars**, L_{pp}, is the distance, in metres, on the summer load waterline from the fore side of the stem to the after side of the rudder post, or to the centre of the rudder stock if there is no rudder post. In craft with unusual stern arrangements the length, L_{pp}, will be specially considered. The forward perpendicular, F.P., is the perpendicular at the intersection of the summer load waterline with the fore side of the stem. The after perpendicular, A.P., is the perpendicular at the intersection of the summer load waterline with the after side of the rudder post or to the centre of the rudder stock for craft without a rudder post.

6.2.3 **Load line length**, L_L, is to be taken as 96 per cent of the total length on a waterline at 85 per cent of the least moulded depth measured from the top of the keel, or as the length from the fore side of the stem to the axis of the rudder stock on that waterline, if that is greater. In craft designed with a rake of keel, the waterline on which this length is measured is to be parallel to the designed waterline. The length L_L is to be measured in metres.

6.2.4 **Length overall**, L_{OA}, is the distance, in metres, measured parallel to the static load waterline from the foreside of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections.

6.2.5 **Length waterline**, L_{WL}, is the distance, in metres, measured on the static load waterline from the foreside of the stem to the after side of the stern or transom.

6.2.6 **Amidships** is to be taken as the middle of the Rule length, L_R, measuring from the forward side of the stem.

6.2.7 **Breadth**, B, is the greatest moulded breadth, in metres, or, for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections. For multi-hull craft it is to be taken as the sum of the breadths of the individual hulls.

6.2.8 **Depth**, D, is measured, in metres, at the middle of the Rule length, L_R, from top of keel to top of the deck beam at side on the uppermost continuous deck, or as defined in appropriate Chapters. When a rounded gunwale is arranged, the depth D is to be measured to the continuation of the moulded deck line at side.

6.2.9 **Draught**, T, is the summer draught, in metres, measured from top of keel.

6.2.10 **Block coefficient**, C_b, is the moulded block coefficient at draught T corresponding to summer load waterline, based on Rule length L_R and moulded breadth B, as follows:

$$C_b = \frac{\text{moulded displacement (m}^3\text{) at draught } T}{L_R \, B \, T}$$

6.3 Freeboard deck

6.3.1 The freeboard deck is normally the uppermost complete deck exposed to weather and sea, which has permanent means of closing all openings in the weather part thereof, and below which all openings in the sides of the craft are fitted with permanent means of watertight closing. It is the deck from which the freeboard is measured.

6.4 Bulkhead deck

6.4.1 Bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried.

6.5 Strength deck

6.5.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective.

6.6 Weather deck

6.6.1 A weather deck is a deck which is exposed to sea and weather loads.

6.6.2 The weather deck is the lowest continuous deck exposed to sea and weather loads, and is not to be taken lower than the bulkhead deck for the determination of the requirements for closing appliances from Chapter 4.

6.7 Wet deck

6.7.1 A wet deck is the lower most exposed surface of the cross-deck structure, connecting the hulls of a multi-hull craft.

6.8 Weathertight

6.8.1 A closing appliance is considered weathertight if it is designed to prevent the passage of water into the craft in any sea conditions.

6.8.2 Generally, all openings in the freeboard deck and in enclosed superstructures are to be provided with weather-tight closing appliances.

6.9 Watertight

6.9.1 A closing appliance is considered watertight if it is designed to prevent the passage of water in either direction under a head of water for which the surrounding structure is designed.

6.9.2 Generally, all openings below the freeboard deck in the outer shell/envelope (and in main bulkheads) are to be fitted with permanent means of watertight closing.

6.10 Position 1 and Position 2

6.10.1 For the purpose of Load Line Conditions of Assignment, there are two basic positions of hatchways, doorways and ventilators defined as follows:

Position 1 — Upon exposed freeboard and raised quarterdecks, and exposed superstructure decks within the forward 0,25 of the Load Line length, L_L.

Position 2 — Upon exposed superstructure decks abaft the forward 0,25 of the load line length, L_L and located at least one standard height of superstructure above the freeboard deck.

Upon exposed superstructure decks within the forward 0,25 of the Load Line length, L_L and located at least two standard heights of superstructure above the freeboard deck.

6.11 Reference system

6.11.1 For hull reference purposes, the craft is divided into 21 equally spaced stations where Station 0 is the after perpendicular, Station 20 is the forward perpendicular, and Station 10 is mid-L_{pp}.

6.12 Co-ordinate system

6.12.1 Unless otherwise stated, the co-ordinate system is as shown in Fig. 1.6.1, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

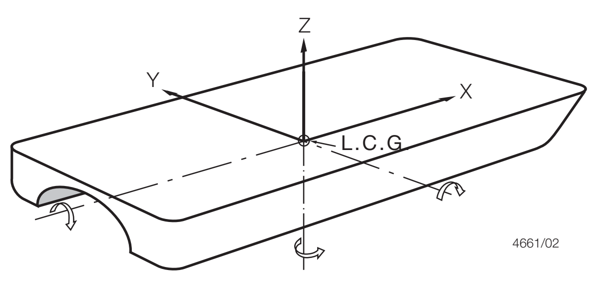


Fig. 1.6.1 Co-ordinate system

6.13 Superstructure

6.13.1 A superstructure is defined as a decked structure on the freeboard deck, extending from side to side of the craft, or with the side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

6.13.2 An enclosed superstructure is a superstructure with:
(a) Enclosing bulkheads of efficient construction;
(b) Access openings, if any, in these bulkheads fitted with doors complying with the requirements of Ch 4,6.5;
(c) All other openings in sides or ends of the superstructure fitted with efficient weathertight means of closing.

6.13.3 The standard height of superstructure for L_L of 75 m or less is to be taken as 1,8 m, and for L_L of 125 m or greater is to be taken as 2,3 m. Intermediate values are to be determined by linear interpolation.

6.14 Deckhouse

6.14.1 A deckhouse is in general defined as a decked structure on or above the freeboard deck with side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

■ *Section 7* Inspection, workmanship and testing procedures

7.1 General

7.1.1 The minimum requirements in respect of inspection, workmanship and testing are contained within Chapter 2, of Parts 6, 7 and 8, of the Rules for craft constructed in steel, aluminium alloy and composite respectively.

7.2 Construction standards

7.2.1 Construction standards for all materials are to be in accordance with National Standards or these Rules whichever are the higher.

7.2.2 The design requirements for welding and structural detail are to be found in Parts 6 and 7 of the Rules for craft constructed in steel and aluminium alloy respectively.

7.2.3 The design requirements for the bonding of all structural detail of composite materials are contained in Part 8.

7.3 Testing procedures

7.3.1 **Definitions.** For the purpose of these procedures the following definitions apply:
(a) **Protective coating** is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.
(b) **Structural testing** is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydro-pneumatic testing, *see* (e), may be carried out instead.
(c) **Leak testing** is an air or other medium test carried out to demonstrate the tightness of the structure.
(d) **Hose testing** is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.
(e) **Hydropneumatic testing** is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in 7.3.4.

7.3.2 **Application**. The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in Table 1.7.1. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired.

7.3.3 **Structural testing**. The attachment of fittings to oiltight surfaces is to be completed before tanks are structurally tested. Where it is intended to carry out structural tests after the protective coating has been applied welds are generally to be leak tested prior to the coating application.

For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating is to be ascertained, and any deficiencies repaired.

7.3.4 **Leak testing**. This is carried out by applying an efficient indicating liquid (e.g. soapy water solution) to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilised state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection. A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a pressure gauge, or alternative equivalent system.

Table 1.7.1 Testing requirements

Item to be tested	Testing procedure	Testing requirement
Double bottom tanks	Structural (1)	The greater of: – head of water up to the top of the overflow – head of water up to the margin line – head of water representing the maximum pressure experienced in service
Cofferdams	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above highest point of tank (4)
Forepeak and aft peak used as tank(3)	Structural	
Tank bulkheads	Structural (1)	The greater of: – head of water up to the top of the overflow – 1,8 m head of water above the highest point of tank (4) – setting pressure of the safety valves, where relevant
Deep tanks	Structural (1)	
Scupper and discharge pipes in way of tanks	Structural (1)	
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Watertight bulkheads, shaft tunnels, flats and recesses, etc.	Hose (2)	*See* 7.3.5
Watertight doors (below freeboard or bulkhead deck) when fitted in place	Hose (6)	
Weathertight hatch covers and closing appliances	Hose	
Forepeak not used as tank	Hose (2)	
Shell doors when fitted in place	Hose (7)	
Chain locker	Structural	The greater of: • head of water up to the top of the spurling pipe • head of water up to the exposed weather deck
Separate oil fuel tanks	Structural	Head of water representing the maximum pressure which could be experienced in service, but not less than 3,5 m
After peak not used as tank	Leak	*See* 7.3.4

NOTES
1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design. (*See also* 7.3.9 and 7.3.10).
2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.
3. Testing of the aft peak is to be carried out after the sterntube has been fitted.
4. The highest point of the tank is generally to exclude hatchways. In holds for liquid cargo or ballast with large hatch openings, the highest point of the tank is to be taken to the top of the hatch.
5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.
6. *See also* SOLAS Reg. II-1/16. Where the door has been subject to the full hydrostatic test before installation, the hose test may be replaced by careful visual examination.
7. For shell doors providing watertight closure, watertightness is to be demonstrated through prototype testing before installation. The testing procedure is to be agreed with LR.

For tanks constructed of steel or aluminium, leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, excepting welds made by automatic processes and on all outfitting penetrations.

Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor, taking account of the quality control procedures of the shipyard. Where exempt from this requirement, leak testing may be carried out after the protective coating has been applied, provided that the welds have been carefully inspected to the satisfaction of the Surveyor.

7.3.5 **Hose testing**. This is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

7.3.6 **Hydropneumatic testing**. When this is performed, the safety precautions identified in 7.3.4 are to be followed.

7.3.7 For tanks of composite construction, leak testing is to be carried out to air pressures as indicated in 7.3.4.

7.3.8 Structural testing may be carried out afloat where testing using water is undesirable in dry-dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in Table 1.7.1. Alternate tanks and cofferdams may be filled to the test head and the bottom and lower side shell in the intermediate empty tanks and cofferdams and all boundaries are to be examined and the remainder of the bottom and lower side shell and boundaries examined when the water is transferred to the remaining tanks.

7.3.9 Where permitted by Table 1.7.1, complete structural testing may be replaced by a combination of leak and structural testing, as follows. The leak test is generally to be carried out on each tank while the craft is in dry-dock or on the building berth.

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.
(b) All deep tanks are to be structurally tested. However, where a number of similar tanks is involved, one typical tank is to be structurally tested and for the remaining tanks the Surveyor may, at his discretion, permit leak testing in lieu of structural testing.
(c) Interconnecting deep and double bottom tanks and 'flume' type stabilisation tanks are to be structurally tested to the test head given in Table 1.7.1.

7.3.10 Equivalent proposals for testing will be considered.

7.3.11 **Trial trip and operational tests**. The items listed in Table 1.7.2 are to be tested on completion of the installation or at sea trials.

Table 1.7.2 Trial trip and operational tests

Item	Requirement
Sliding watertight doors	To be operated under working conditions.
Windlass	An anchoring test is to be carried out in the presence of the Surveyor. The test is to demonstrate that the windlass with brakes, etc., functions satisfactorily and that the power to raise the anchor can be developed and satisfies the Rule requirements. For Rule requirements, *see* Ch 5,8.
Steering gear, main and auxiliary	To be tested under working conditions, to the satisfaction of the Surveyors, to demonstrate that the Rule requirements are met. For Rule requirements, *see* Pt 14, Ch 1.
Davits and deck cranes	To be tested under working conditions to proof load to the satisfaction of the Surveyors.
Fire flaps	To be operated under working conditions to the satisfaction of the Surveyors.
Means of escape	Alternative means of escape from machinery and accommodation spaces is to be proven to the satisfaction of the Surveyors. For Rule requirements, *see* Ch 2,4.10.

■ *Section 8*
Building tolerances and associated repairs

8.1 Tolerances – General

8.1.1 Tolerances to be used regarding the acceptability of defects affecting raw materials are to be in accordance with 8.2.

8.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/Builders and the Surveyor and acceptable Standards agreed subject to the requirements of this Chapter or National Authority requirements where applicable. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.
(b) In secondary structure.
(c) Aesthetically pleasing.

8.1.3 The requirements in respect of constructional misalignment of steel/aluminium craft are to be found in 8.6. The requirements for construction using composite materials are contained in Pt 8, Ch 2.

8.2 Raw material surface tolerances

8.2.1 The surface cleanliness of steel/aluminium alloy materials in preparation for painting is to be in accordance with National or paint Manufacturer's Standards.

8.2.2 Where approved corrosion control coatings are to be used the quality of the surface treatment is to be in accordance with the grade specified in the approval documents.

8.3 Surface defects

8.3.1 The limits of depth and extent of surface defects on plate, cast or forged materials in relation to the material plate thickness are shown in Table 1.8.1.

8.3.2 Defects are to be made good by grinding only subject to the plate thickness not being reduced by more than seven per cent of the nominal thickness or 3 mm whichever is the lower, and the area involved not exceeding two per cent of the surface area.

8.3.3 When the limits in 8.3.1 are exceeded, plates may be made good by weld repair in accordance with the requirements specified in Chapter 13 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

8.3.4 Where the depth of the deepest imperfection exceeds 20 per cent of the nominal thickness, or the defective area exceeds two per cent of the total surface area, such areas are to be cropped and replaced. *See* 8.5.

Table 1.8.1 Limits of surface defects

Normal thickness of material (mm)	Maximum permissible depth of defect (mm)	
	Area affected – Unlimited	Area affected ≤ 5% of Surface
< 8 8 to 25 25 to 40 ≥ 40	0,2 0,3 0,4 0,5	0,4 0,5 0,6 0,8

NOTES
1. Defects are to be measured after shot blasting or plate cleaning.
2. The depth of the deepest imperfection is to be considered.
3. Defects not exceeding the limits shown need not be repaired.
4. Where the depth of the defect reduces the material thickness to below the rolling/forging/casting tolerance (stated in the Rules for Materials) the values in column 2 and 3 will be accepted provided the areas involved do not exceed 15% and 2% respectively, of the plate/forging/casting surface.
5. Defects exceeding the above limits are to be repaired.
6. Crack-like defects are always to be repaired irrespective of their depth.

8.3.5 Complete removal of the defects is to be verified by suitable non-destructive examination techniques and after welding the repair is to be proved free from further defects. The complete removal of defects is to be verified by non-destructive examination in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

8.3.6 Care is to be taken in the repair of defects in higher tensile steel, and aluminium alloy materials. Low hydrogen electrodes with similar properties to the higher tensile steel is to be used with preheating as necessary. Aluminium alloys are to be heat treated after repair, *see* Pt 7, Ch 2,3.

8.4 Plate laminations

8.4.1 Plates in which laminations are suspected or detected are to be ultrasonically tested to determine the full extent of such laminations.

8.4.2 Where laminations are confined to the plate edge, are less than 300 mm long and whose penetration is not more than half the plate thickness, then the defect may be chipped or ground out and rebuilt with weld material.

8.4.3 Where laminations are isolated, located near to the plate surface, and where the total area of the defect does not exceed two per cent of the surface area of the plate, the defect may be repaired as in 8.4.2.

8.4.4 Defective plate, with defects in excess of those stated in 8.4.2 and 8.4.3, is to be cropped back and replaced. *See* 8.5.

8.4.5 Complete removal of the defect is to be verified by non-destructive examination, and after welding, the repair is to be proved free from further defects.

8.5 Part replacement of plates

8.5.1 When defects exceed the limits laid down in 8.3.4 and 8.4.4 above, the portion of the plate affected is to be cropped and replaced, *see* Table 1.8.2.

8.6 Structural misalignment and fit (steel and aluminium)

8.6.1 For the requirements for the alignment and structural continuity of joints, *see* Chapter 2 of Parts 6 and 7.

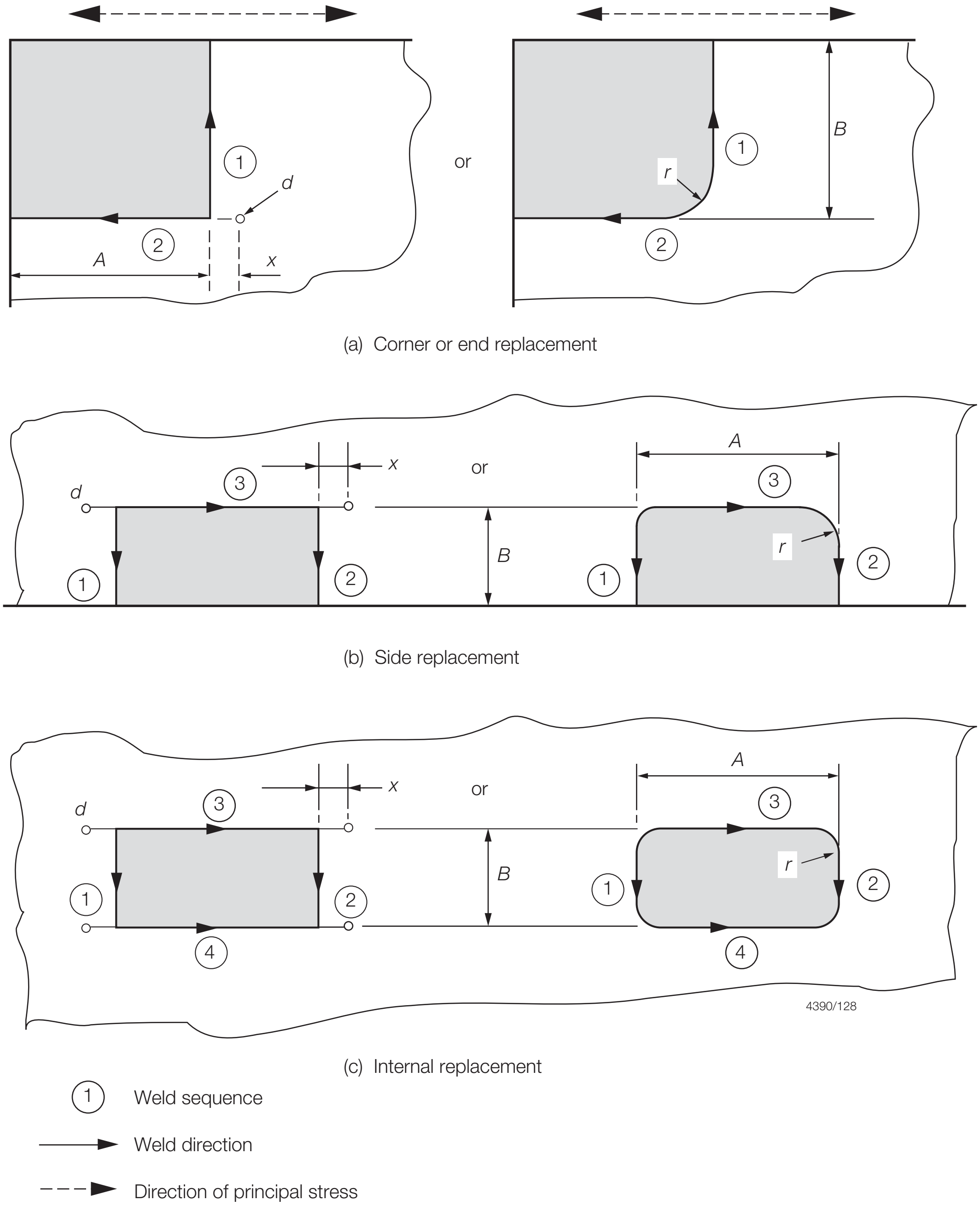
8.6.2 Tables 1.8.3, 1.8.4 and 1.8.5 define the minimum limits of accuracy required to be achieved in the various welded joint designs. When these values are not achieved, the defects are to be discussed and agreed by the Builder and the Surveyor before remedial action is taken.

8.6.3 Welding defects are generally to be dealt with in accordance with Chapter 13 of the Rules for Materials. Limits for weld undercut and remedial action to be taken depends on plate thickness and are to be discussed and agreed by the Builder and the Surveyor prior to commencement of repairs.

Table 1.8.2 Part replacement of plates

	Parts to be replaced	Shell, strength deck, tank top, top and bottom strakes of longitudinal bulkheads	Elsewhere
A x B	End and corner of plate	1000 x 1000	1000 x 300
	Side of plate	1000 x 300	1000 x 300
	Insert	1000 x 300	1000 x 300

Line of plate replacement to be not less than 100 from extreme edge of defect.
All dimensions are in mm.



(a) Corner or end replacement

(b) Side replacement

(c) Internal replacement

NOTES
1. All dimensions are minimum.
2. Rolling direction of replaced plate to be the same as that of the parent plate.
3. Minimum distance from outermost defect to line of weld – 100 mm.
4. Dimensions in millimetres:
   x = 50
   d = 1,5 x plate thickness with minimum 6 and maximum 20
   r = 75 minimum

Table 1.8.3 Structural misalignment and fit (steel and aluminium)

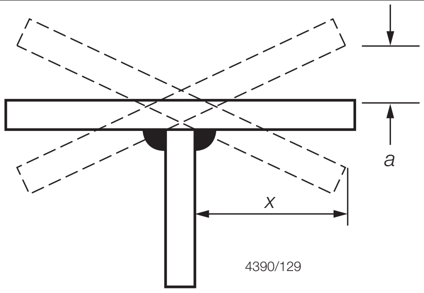
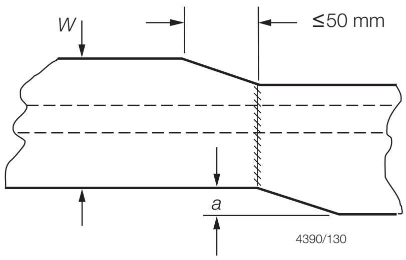
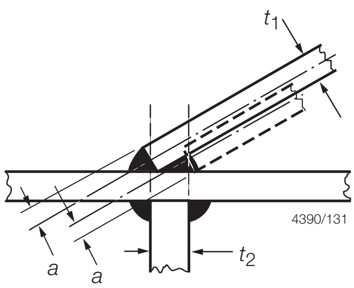
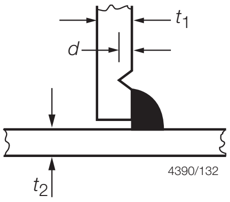
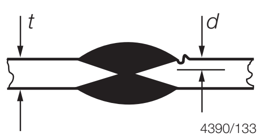
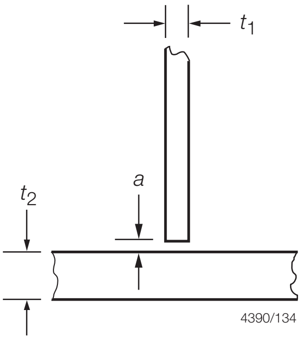
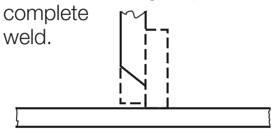
Joint	Location	Acceptable dimensions (mm)	Remedial action	
	Fabricated frames Beams, girders and longitudinals	$a \leq \pm$ 0,03 x	$a > \pm$ 0,03 x	Reject
	Butt welded face flats primary structure	$a \leq 0{,}03W$ (max 6 mm)	$a > 0{,}03W$	Reject
	Secondary structure	$a \leq 0{,}04W$ (max 8 mm)	$a > 0{,}04W$	Reject
	Obtuse angle fillet weld	$a \leq t_1/2$	$a > t_1/2$	Reject
	All areas	$d \leq 0{,}1t_1$ (max 0,8 mm)	$d > 0{,}1t_1$	Repair by welding or grinding depends on thickness 't_1' in accordance with 8.3
	All areas	$d \leq 0{,}1t$ (max 0,8 mm)	$d > 0{,}1t$	As above

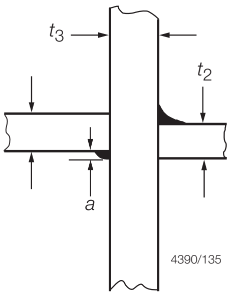
Table 1.8.4 Structural misalignment and fit (steel and aluminium)

<table>
<tr><th>Joint</th><th>Location</th><th>Permitted misalignment</th><th colspan="2">Remedial action</th></tr>
<tr><td rowspan="5"></td><td rowspan="3">All areas
(Continuous fillet weld)</td><td rowspan="3">a (mm)

a < 0,25t1
(max = 1 mm)</td><td>a (mm)

0,25t1 to 0,5t1
(t1 max = 5 mm)</td><td>Increase weld leg length by ‘a’</td></tr>
<tr><td>0,5t1 to t1
(t1 max = 15 mm)</td><td>Vee material to +/–45°. Fit backing strip and weld. Remove backing strip and complete weld.
</td></tr>
<tr><td>a > t1</td><td>Realign and replace</td></tr>
<tr><td rowspan="2">All areas
(intermittent weld)</td><td rowspan="2">< 0,25t1</td><td>0,25 to 0,5t1
(t1 max = 3 mm)

0,25t1 to 0,5t1
(t1 max = 5 mm)</td><td>Increase weld lengths by 50%

Continuous weld</td></tr>
<tr><td>a > t1</td><td>As for continuous weld above</td></tr>
<tr><td></td><td>Strength members

Others

Higher tensile steel joint in designated critical areas</td><td>a ≤ t2/3

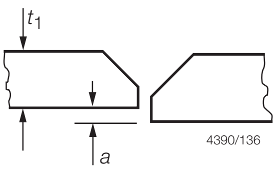
a ≤ t2/2

a ≤ t3/3</td><td>t2/3 ≤ a ≤ t1/2

a > t2/2

a > t3/3</td><td>Increase weld leg length of welds by 10%

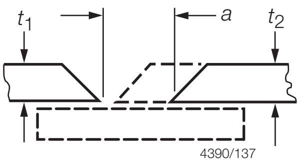
Realign

Realign</td></tr>
<tr><td></td><td>Strength members

Others</td><td>a ≤ 0,15t1
(max 3,0 mm)

a ≤ 0,2t1
(max 3,0 mm)</td><td>a > 0,15t1

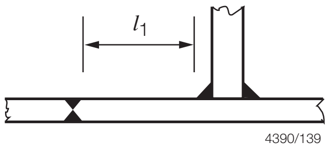
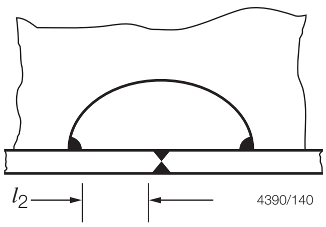
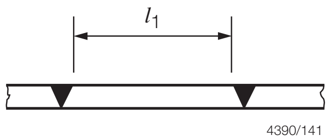
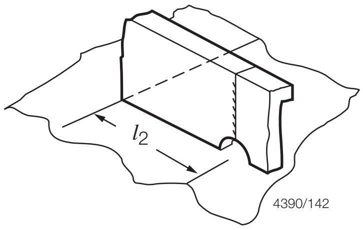
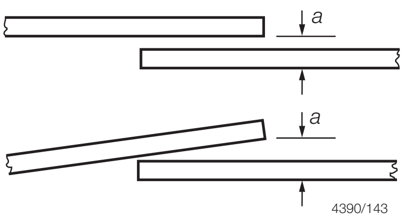
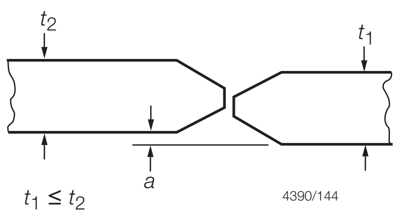
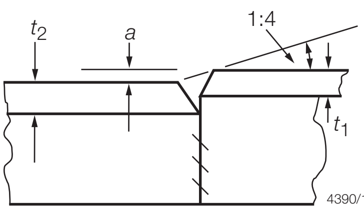
a > 0,2t1</td><td>Realign

Realign</td></tr>
<tr><td></td><td>All areas</td><td>a in accordance with weld procedure</td><td>a ≤ t1

a > t1
(max 10 mm)</td><td>Build one side of butt until a in accordance with weld procedure

Cut back 150 mm and fit insert plate</td></tr>
</table>

Table 1.8.5 Structural misalignment and fit (steel and aluminium)

Joint	Location	Acceptable dimensions (mm)	Remedial action	
	All	$l_1 \geq 40$ mm	–	Adjust to suit
	All	$l_2 \geq 20$ mm	–	Adjust to suit
	All	$l_1 > 50$ mm	$l_1 < 30$ mm	Treat as an insert
	All	$l_2 \geq 20$ mm	$l_2 < 15$ mm	Adjust to suit
	All All	$a \leq 1{,}0$ $a \leq 1{,}0$	$a < 5$ $a \leq 5$	Increase weld leg length by actual '*a*' Adjust to suit
	Strength members Other	$a \leq 0{,}15t_1$ (max 3,0 mm) $a \leq 0{,}2t_1$ (max 3,0 mm)	$a > 0{,}15t_1$ $a > 0{,}2t_1$	Reject Reject
	All	For angle or tee longitudinal $a \leq 0{,}2t_1$ For offset bulb longitudinal $a \leq 0{,}2t_2$	$a > 0{,}2t_1$ $a > 0{,}2t_2$	Reject Reject

8.7 Post welding plate deformation

8.7.1 Post welding plate deformation for steel and aluminium alloy construction is to be limited, *see* Table 1.8.6 and Fig. 1.8.1.

Table 1.8.6 Plate deformation limits

Position	s/t	δ_p/s
in 0,6L amidship	≤ 80 > 80	1/100 1/75
Remainder	all	1/50

Where
s = stiffener spacing, in mm
t = plating thickness, in mm
δ_p = panel deflection, in mm

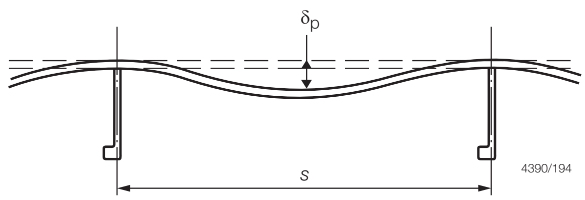


Fig. 1.8.1 Measurement of plate deformation

8.7.2 Deformation outside the limits of Fig. 1.8.1 is to be faired by local heating or the plating renewed.

8.7.3 Local heating of steel is not to exceed 900°C (red heat) when flame straightening is employed.

8.7.4 Local heating of aluminium alloys is not to be carried out. All repairs are to be by renewal of plating.

Section

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in applying the structural requirements given in Parts 4, 6, 7 and 8. In particular, consideration has been given to the layout of the Rules as regards the different regions of the craft, principles for taper of hull scantlings, definition of span point, derivation of section moduli and basic design loading for deck structures. Principles for subdivision are also covered.

1.1.2 Where additional requirements relating to particular craft types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

■ *Section 2*
Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the craft will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, cargo, passengers, ballast, bunkers and other operational loads. However, the Rules assume that the nature and stowage of the cargo, ballast, etc., are such as to avoid excessive structural stress.

2.2.2 Design loads and pressures as given in Part 5, are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the craft are not impaired. However these aspects are outwith the scope of classification, *see* Pt 1, Ch 2,1.4.

2.3 Definition of requirements

2.3.1 Static loads are based on standard conditions defined in Part 5, or determined from loading conditions submitted by the Builder.

2.3.2 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.3.3 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode, i.e. impact, slamming and hogging and sagging wave landing conditions.

2.3.4 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed loadings, etc., of the craft.

2.3.5 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, etc., are not specifically indicated within these Rules. However the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.4 Definitions and structural terms

2.4.1 The various definitions and structural terms for use throughout this Chapter are as indicated within the appropriate Section.

2.5 Symbols

2.5.1 The various symbols for use throughout this Chapter are as indicated within the appropriate Section.

Section 3
Structural idealisation

3.1 General

3.1.1 The scantling formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, in association with an appropriate concentrated or distributed load for steel and aluminium craft.

3.1.2 Apart from a local requirement for web or flange thicknesses, the stiffener, beam or girder strength is defined by a section modulus and moment of inertia requirement.

3.1.3 For the derivation of scantlings for fibre composite structures, the formulae are based on equivalent load carrying capability, with limitations on both allowable stress and strain, in addition to deflection controls.

3.2 Geometric properties of sections

3.2.1 The symbols used in this sub-Section are defined as follows:

b = the actual width, in metres, of the load-bearing plating, i.e. one-half of the sum of spacings between parallel adjacent members or equivalent supports

$f = 0{,}3\left(\frac{l}{b}\right)^{2/3}$

but is not to exceed 1,0. Values of this factor are given in Table 2.3.1

l = the overall length, in metres, of the primary support member, as indicated in Fig. 3.1.2 in Pt 6, Ch 3 and Pt 7, Ch 3, respectively, for steel and aluminium alloy construction and Fig. 3.1.3 of Pt 8, Ch 3 for composite construction

t_p = the thickness, in mm, of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.2 The effective geometric properties of rolled or built sections may be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the attached plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

3.2.3 The geometric properties of rolled or built stiffener sections and of swedges are to be calculated in association with effective area of attached load bearing plating of thickness, t_p, mm and of width as given by Pt 6, Ch 3,1.10 or Pt 7, Ch 3,1.11 for steel and aluminium alloy construction respectively. In no case, however, is the width of plating to be taken as greater than either the spacing of the stiffeners or the width of the flat plating between swedges, whichever is appropriate. The thickness, t_p, is the actual thickness of the attached plating. Where this varies, the mean thickness over the appropriate span is to be used.

3.2.4 The effective section modulus of a corrugation over a spacing, s_c, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

$$z = \frac{d_w\,(3b\,t_p + c\,t_w)}{6000}\ \text{cm}^3$$

where

d_w, b, t_p, c and t_w are measured, in mm, and are as shown in Fig. 2.3.1. The value of b is to be taken not greater than:

$50t_p\sqrt{\frac{235}{\sigma_0}}$ for welded corrugations

$60t_p\sqrt{\frac{235}{\sigma_0}}$ for cold formed corrugations

where

σ_0 is defined in Ch 3,1.2.

The value of θ is not to be taken less than 40°. The moment of inertia is to be calculated from:

$$I = 0{,}05 d_w Z\ \text{cm}^4$$

Table 2.3.1 Values of factor *f*

$\frac{l}{b}$	f	$\frac{l}{b}$	f
0,5	0,19	3,5	0,69
1,0	0,30	4,0	0,76
1,5	0,39	4,5	0,82
2,0	0,48	5,0	0,88
2,5	0,55	5,5	0,94
3,0	0,62	6,0 and above	1,00

NOTE
Intermediate values to be obtained by linear interpolation.

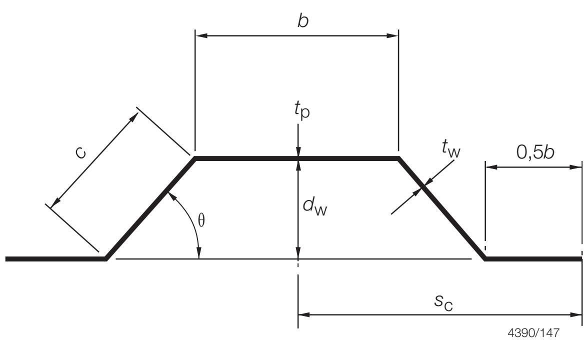


Fig. 2.3.1 Corrugation

3.2.5 The section modulus of a double plate bulkhead over a spacing, *b,* may be calculated as:

$$Z = \frac{d_w\,(6f\,b\,t_p + d_w\,t_w)}{6000}\ \text{cm}^3$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in Fig. 2.3.2.

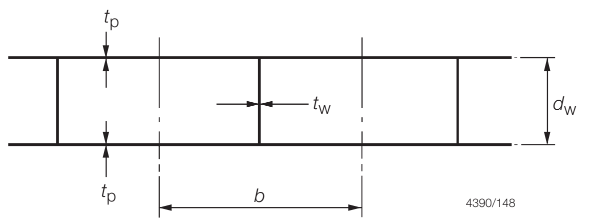


Fig. 2.3.2 Double plate bulkhead

3.2.6 The effective section modulus of a fabricated section may be taken as:

$$Z = \frac{a\,d_w}{10} + \frac{t_w\,d_w^2}{6000}\left(1 + \frac{200\,(A - a)}{200A + t_w\,d_w}\right)\ \text{cm}^3$$

where

- a = the area of the face plate of the member, in cm^2
- d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken
- t_w = the thickness of the web of the section, in mm
- A = the area, in cm^2, of the attached plating, *see* 3.2.7 If the calculated value of A is less than the face area, a, then A is to be taken as equal to a.

3.2.7 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) are to be calculated in association with an effective area of attached load bearing plating, A, determined as follows:

(a) For a member attached to plane plating:
$A = 10f\,b\,t_p$ cm^2
where
f is as defined in 3.2.1.

(b) For a member attached to corrugated plating and parallel to the corrugations:
$A = 10b\,t_p$ cm^2
(*See* Fig. 2.3.1)

(c) For a member attached to corrugated plating and at right angles to the corrugations:
A is to be taken as equivalent to the area of the face plate of the member.

3.3 Determination of span point

3.3.1 The effective span, l_e, of a stiffening member is to be as defined in Parts 6, 7 and 8, for steel, aluminium alloy and composite construction respectively.

3.4 Calculation of hull section properties

3.4.1 The particular requirements for the calculation of the hull section modulus for craft of steel and aluminium alloy construction are defined in Pt 6, Ch 6 and Pt 7, Ch 6 respectively. The particular requirements for the hull section stiffness for craft of composite construction are defined in Pt 8, Ch 6.

Section 4
Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads are, in general, to extend to the uppermost continuous watertight deck, hereinafter referred to as the bulkhead deck, and their construction is to be in accordance with Parts 6, 7 and 8 as appropriate.

4.1.2 Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with Ch 4,2.

4.2 Number and disposition of bulkheads

4.2.1 All craft with a Rule length, L_R, greater than 15 m are to have a collision bulkhead.

4.2.2 In motor craft with a Rule length, L_R, less than or equal to 15 m, the machinery is to be enclosed by gastight bulkheads to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

4.2.3 In all craft with a Rule length, L_R, less than or equal to 25 m, the sterntube is to be enclosed in a watertight compartment, wherever practicable.

4.2.4 All craft with a Rule length, L_R, greater than 25 m are to have an aft peak bulkhead, generally enclosing the sterntubes in a watertight compartment.

4.2.5 All craft with a Rule length, L_R, greater than 15 m are to have a watertight bulkhead at each end of the machinery space, where the machinery is amidships or a watertight bulkhead at the forward end of the machinery space, where the machinery is aft.

4.2.6 All craft with a Rule length, L_R, greater than 25 m are to have a watertight bulkhead at each end of the machinery space, with the aft peak bulkhead forming the aft bulkhead of the machinery space, where the machinery is aft.

4.2.7 Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with Table 2.4.1.

Table 2.4.1 Total number of bulkheads

Length, L_R, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft
> 15 ≤ 25	3	2
> 25 ≤ 65	4	3*
> 65 ≤ 85	4	4*
> 85 ≤ 90	5	5*
> 90 ≤ 105	5	5*
> 105 ≤ 115	6	5*
> 115 ≤ 125	6	6*
> 125 ≤ 145	7	6*
> 145	To be individually considered	
*With afterpeak bulkhead forming after boundary of machinery space		

4.2.8 Bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually great, the transverse strength of the craft is to be maintained by fitting of web frames, increased framing, etc., and details are to be submitted.

4.2.9 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the requirements of a special trade.

4.2.10 Where applicable, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the requirements of the National Authority.

4.3 Collision bulkhead

4.3.1 The collision bulkhead in all craft other than passenger craft, patrol craft and yachts is to be positioned as detailed in Table 2.4.2. Consideration will, however, be given to proposals for the collision bulkhead to be positioned slightly further aft on Arrangement (b) craft, but not more than $0{,}08L_L$ from the fore end of L_L, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the freeboard deck becoming submerged, or any unacceptable loss of stability. Special consideration may be given to the extent of the collision bulkhead above the bulkhead deck for multi-hull craft.

4.3.2 The collision bulkhead in passenger craft, patrol craft and yachts is to be in accordance with the following:

(a) A craft shall have a forepeak or collision bulkhead, which shall be watertight up to the bulkhead deck. (The bulkhead deck is the uppermost deck up to which the transverse watertight bulkheads are carried, *see* 4.2.10). This bulkhead is to be positioned as detailed in Table 2.4.3.

Table 2.4.2 Collision bulkhead position (excluding passenger craft, patrol craft and yachts)

Arrangement	Length, L_L	Distance of collision bulkhead aft of the fore end of L_L, in metres	
		Minimum	Maximum
(a)	≤ 150	$0{,}05L_L$	$0{,}08L_L$
(b)	≤ 150	$0{,}05L_L - f_1$	$0{,}08L_L - f_1$

Symbols and definitions

$f_1 = \dfrac{G}{2}$ or $0{,}015L_L$, whichever is the lesser

G = projection of bulbous bow forward of fore end of L_L, in metres

L_L is as defined in Ch 1,6.2

Arrangement (a) A craft that has no part of its underwater body extending forward of the fore end of L_L

Arrangement (b) A craft with part of its underwater body extending forward of the fore end of L_L (e.g. bulbous bow)

(b) If the craft has a long forward superstructure, the forepeak or collision bulkhead is to be extended weathertight to the deck next above the bulkhead deck. The extension need not be fitted directly over the bulkhead below, provided it is located within the limits specified in Table 2.4.3 with the exemption permitted by 4.6.3 and the part of the bulkhead deck which forms the step is made effectively weathertight.

4.3.3 Alternative arrangements may be submitted for consideration in the case of sailing and auxiliary craft.

4.3.4 For craft with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.5 Accesses are not to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, to open into the fore peak compartment and consideration will be given to operation from one side only.

4.4 Aft peak bulkhead

4.4.1 An aft peak bulkhead, where required to be fitted (in each half of a multi-hull craft) is, in general, to enclose the sterntube, water jet unit, etc., in a watertight compartment. In twin screw craft the sterntubes are to be enclosed in suitable watertight spaces. *See also* Table 2.4.1.

Table 2.4.3 Collision bulkhead for passenger craft, patrol craft and yachts

Arrangement	Distance of collision bulkhead aft of fore perpendicular, in metres	
	Minimum	Maximum
(a)	$0{,}05L_{pp}$	$3 + 0{,}05L_{pp}$
(b)	$0{,}05L_{pp} - f$	$3 + 0{,}05L_{pp} - f$
Symbols and definitions		
$f = \frac{G}{2}$ or $0{,}015L_{pp}$, whichever is the lesser G = projection of bulbous bow forward of fore perpendicular, in metres L_{pp} is as defined in Ch 1, 6.2 Arrangement (a) A craft that has no part of its underwater body extending forward of the fore perpendicular. Arrangement (b) A craft with part of its underwater body extending forward of the fore perpendicular, e.g. bulbous bow.		

4.5 Height of bulkhead

4.5.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of craft with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a craft is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the deck next above the freeboard deck. Where the collision bulkhead extends above the freeboard deck, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor. In passenger craft the aft peak bulkhead is to extend watertight to the bulkhead deck. However, it may be stepped below the bulkhead deck provided the degree of safety of the craft as regards watertight subdivision is not thereby diminished.

4.5.3 The remaining watertight bulkheads are to extend to the bulkhead deck. In passenger craft of restricted draught and all craft of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats and loading ramps

4.6.1 Watertight recesses in bulkheads are generally to be so framed and stiffened as to provide strength and stiffness equivalent to the requirements for watertight bulkheads.

4.6.2 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in 4.3.1 or 4.3.3 as applicable. Where the bulkhead is extended above the freeboard deck, or bulkhead deck in passenger craft, the extension need only be to weathertight standards. If a step occurs at that deck, the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.3 In craft fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the freeboard or bulkhead deck, that part of the ramp which is more than 2,30 m above the freeboard or bulkhead deck may extend forward of the minimum limit specified in Table 2.4.2 or Table 2.4.3 as appropriate. Such a ramp is to be weathertight over its complete length.

4.7 Gastight bulkheads

4.7.1 Where bulkheads are required to be gastight in accordance with 4.2.2, and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc., gastight glands are to be provided to maintain the gastight integrity.

4.8 Tank bulkheads

4.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

4.8.2 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side of the craft. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to be as required for boundary bulkheads. If perforated, the modulus of stiffeners may be 50 per cent of that required for boundary bulkheads, using a head measured to the crown of the tank.

4.8.3 The arm length of brackets at the ends of the stiffeners is to be 2,5 times the depth of stiffener. The thickness of the brackets is to be not less than the web thickness of the stiffener.

4.8.4 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

4.9 Cofferdams

4.9.1 Tanks carrying oil fuel or lubricating oil are to be separated by cofferdams from those carrying feed water, fresh water, edible oil or similar oils. Similarly tanks carrying vegetable or similar oils are to be separated by cofferdams from those carrying fresh or feed water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

4.9.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying oil fuel. However such cofferdams need not be fitted provided that:

(a) Common boundaries of lubricating oil and oil fuel tanks have full penetration welds.

(b) The tanks are arranged such that the oil fuel tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.9.3 Cofferdams are not required between oil fuel double bottom tanks and deep tanks above, provided that the inner bottom plating is not subjected to a head of oil fuel.

4.9.4 Where fitted, cofferdams are to be suitably ventilated.

4.9.5 If oil fuel tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from an engine room fire. *See* Part 17 as applicable.

4.9.6 In passenger craft, water ballast is, in general, not to be carried in tanks intended for oil fuel. Attention is drawn to the Statutory Regulations issued by National Authorities in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78.*

4.10 Means of escape

4.10.1 For the requirements for means of escape on service craft and yachts over 24 m in length, *see* Pt 17, Ch 2 and Pt 17, Ch 3 respectively.

4.10.2 The arrangement of the hull is to be such that all underdeck compartments are as accessible as practicable and provided with a satisfactory means of escape. Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.11 Carriage of low flash point fuels

4.11.1 Special provision is to be made for the carriage of low flash point fuel in accordance with Pt 15, Ch 3,5.

■ *Section 5*
Fore and aft end arrangements

5.1 General

5.1.1 The requirements in respect of the general constructional arrangements for mono-hull craft covered by the Rules are contained within this Section.

5.2 Structural configuration

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.3 Structural continuity

5.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.3.2 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending aft of 0,15L from the F.P., longitudinal framing at the upper deck and topsides is generally to be continued forward of the end bulkhead of this superstructure.

5.4 Minimum bow height and reserve buoyancy

5.4.1 All sea-going craft are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the summer load waterline to the top of the exposed deck at side at the F.P. is not less than:

$$H_b = \left(6075\left(\frac{L_L}{100}\right) - 1875\left(\frac{L_L}{100}\right)^2 + 200\left(\frac{L_L}{100}\right)^3\right) \times \left(2{,}08 + 0{,}609C_b - 1{,}603C_{wf} - 0{,}0129\left(\frac{L_L}{d_1}\right)\right)$$

where

d_1 = draught at 85 per cent of the depth D, in metres

A_{wf} = waterplane area forward of $\frac{L_L}{2}$ at draught d_1, in m^2

B = moulded breadth, in metres

C_b = block coefficient as defined in the Load Lines Convention

C_{wf} = the waterplane area coefficient forward of

$$C_{wf} = \frac{A_{wf}}{\left(\frac{L_L}{2}\right) \times B}$$

H_b = minimum bow height

L_L = Load Line length, in metres.

5.4.2 Craft which are designed to suit exceptional operational requirements, restricted in their service to Group G1, or of novel configuration will be specially considered on the basis of the Rules.

5.4.3 Where the bow height required in 5.4.1 is obtained by sheer, the sheer shall extend for at least 15 per cent of the length of the craft measured abaft the forward end of L_L. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_L abaft the forward end of L_L, and shall be enclosed.

5.4.4 Craft shall have additional reserve buoyancy in the fore end in accordance with the Load Lines Convention.

5.5 Bow crumple zone

5.5.1 In general, the bow crumple zone is that space forward of the collision bulkhead. Passenger and crew accommodation and the carriage of fuel and other oils is not permitted in the bow crumple zone.

5.6 Strengthening of bottom forward

5.6.1 Except for craft with **G1** and **G2** service notations, additional strengthening of bottom forward is required for craft with the rule length, L_R, greater than 65 m. Details are to be submitted for consideration.

5.7 Bulbous bows

5.7.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.7.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.7.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.7.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.7.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.7.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

5.8 Strengthening against bow flare slamming

5.8.1 Where a craft has pronounced flare or rake of bow, the structure in the forward region will be subject to special consideration, and the scantlings and arrangements may require additional strengthening.

■ *Section 6* Machinery space arrangements

6.1 General

6.1.1 This Section applies to all craft types. Only requirements particular to machinery spaces, including protected machinery casings and engine seatings, are given. For other scantlings and arrangement requirements, *see* the relevant Chapter in Parts 6, 7 and 8.

6.2 Structural configuration

6.2.1 Requirements are given for craft constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 For machinery spaces situated aft, where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged. *See also* 5.3.

6.2.3 The maximum spacing, S_{max}, of web frames in longitudinally framed machinery spaces is not to exceed 3,8 m. Additionally for transversely framed craft, in way of a machinery space situated adjacent to the aft peak, the spacing of web frames is not to exceed six transverse frame spaces.

6.2.4 Where the machinery space is situated in the midship region, it is recommended that web frames be fitted in the engineroom, spaced not more than six frame spaces apart and extending from the tank top to the level of the lowest deck above the load waterline. The scantlings of these webs are to be such that the combined section modulus of the web frame and the main or 'tween deck frames is 50 per cent greater than that required for normal transverse framing. These webs may be omitted if the section modulus of the transverse frames is increased by 50 per cent.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the craft is omitted in way of a machinery space.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 In motor craft having a Rule length, L_R, less than 15 m, the machinery is to be enclosed by gastight decks to protect accommodation spaces from gas and vapour fumes from machinery, exhaust and fuel systems.

6.5 Side shell structure

6.5.1 Side shell structure is to be constructed in accordance with the scantlings indicated in Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

6.5.2 General requirements for web frames are given in this Section for both longitudinal and transverse framing systems. Where longitudinal framing is adopted in the midship region it is to be carried as far forward and aft as practicable.

6.5.3 A transverse framing system is to be additionally reinforced by web frames fitted six frame spaces apart. Where a longitudinal framing system is adopted, the spacing of the transverses is not to exceed 2,5 m.

6.6 Double and single bottom structure

6.6.1 Where the Rule length, L_R, of the craft exceeds 50 m, a double bottom is to be fitted in the hull (or hulls in multi-hull craft), extending from the collision bulkhead to the forward watertight bulkhead for the machinery space.

6.6.2 Where the Rule length, L_R, of the craft exceeds 61 m, a double bottom is to be fitted outside the machinery space and is to extend to the collision bulkhead and the aft peak bulkhead. Where no aft peak bulkhead is fitted, the extent of the double bottom will be specially considered.

6.6.3 Where the Rule length, L_R, of the craft exceeds 76 m, the double bottom is to extend throughout the length of the craft.

6.6.4 For multi-hull craft and other craft which are to be assigned an **HSC** notation or which are to operate within **Restricted Service Groups G1**, **G2**, **G2A** and **G3**, the extent of the double bottom will be specially considered depending on the number of transverse watertight bulkheads and the requirements of the National Authority concerning stability after damage.

6.6.5 Margin plates and drainage wells are to be provided as necessary and subject to special consideration.

6.6.6 The scantlings of bottom stiffening, floors, centre girders and side girders are to be in accordance with the appropriate Sections of Parts 6, 7 and 8 of the Rules, for craft built in steel, aluminium alloy and composite respectively.

6.6.7 In motor craft the thickness of the floors in machinery spaces is to be 1mm greater than that required by the appropriate Sections of Parts 6 and 7 of the Rules, for craft built in steel and aluminium alloy respectively.

6.6.8 In craft having considerable rise of floor, the depth of the floor plate, or its height at side, may require to be increased. The transverse extent of double bottom will be specially considered.

6.6.9 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions.

6.6.10 A centreline girder is to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m. Where the breadth of the floors at the upper edge exceeds 6,0 m a side girder is also to be fitted each side of the centre girder.

6.6.11 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity.

6.6.12 Centreline girders fitted in association with flat plate keels are to be formed of intercostal or continuous plates with a continuous face flat welded on the upper edge.

6.6.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with 6.8.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with Ch 3,9.8, of Parts 6 and 7, for craft built in steel and aluminium alloy respectively.

6.7.2 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably increased. *See also* Ch 3,10, Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.7.3 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with Ch 3,7, of Parts 6, 7 and 8, for craft built in steel, aluminium alloy and composite respectively.

6.9 Machinery seatings

6.9.1 Main and auxiliary engines in motor and auxiliary sailing craft are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational, thrust, torque and vibrating forces which may be imposed upon them.

6.9.2 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and be adequately supported by transverse floors or brackets.

6.9.3 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics with regard to out of balance forces.

6.9.4 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Small brackets may be required under the top plate in way of holding down bolts.

6.9.5 For gas turbine installations, seats are to be so designed as to provide effective support and ensure their proper alignment with the gearing, and where applicable allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

6.9.6 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

6.10 Thrust blocks

6.10.1 Main engines and thrust bearings are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them.

6.10.2 For initial guidance, it is recommended that the scantlings for oil engine seatings be as indicated in 6.9.3.

■ *Section 7* Superstructures, deckhouses and bulwarks

7.1 General

7.1.1 Superstructures, deckhouses and bulwarks are to be constructed in accordance with the scantlings indicated in Ch 3,9 of Parts 6, 7 and 8, for steel, aluminium alloy and composite structures respectively.

7.2 Definition of tiers

7.2.1 The lowest, or first tier, is normally that which is directly situated on the deck to which *D* is measured. The second tier is the next tier above the lowest tier and so on. *See* Fig. 2.7.1.

7.2.2 Where the vertical distance between the weatherdeck and the summer load waterline is equal to or greater than the sum of the minimum freeboard and one standard superstructure height, then proposals to treat the first tier erection as a second tier, and so on, will be specially considered. The standard height of superstructure is the height defined in Ch 1,6.13.3. *See* Fig. 2.7.1.

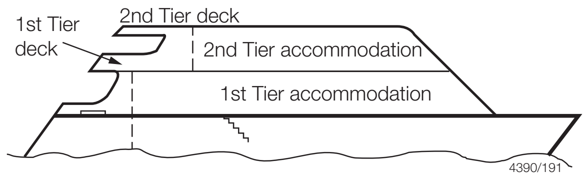


Fig. 2.7.1 Definition of tiers

7.2.3 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

7.3 Unusual designs

7.3.1 Craft or structural arrangements which are of unusual design, form or proportions will be individually considered. Special features will be considered in each separate case.

■ *Section 8* Particular requirements for multi-hulls

8.1 General

8.1.1 The requirements indicated in this Section are particular to multi-hull craft and are to be applied in addition to the general requirements of this Chapter.

8.1.2 The craft is to be considered as one complete structure when determining the minimum geometric summer freeboard. The block coefficient is to be calculated using the actual displacement determined from the hydrostatic data and using the total breadth of the structure and not just a single hull.

8.1.3 If, by using normal procedures, the minimum geometric summer freeboard determined is unreasonable for the operation of the craft, special consideration may be given, on a case by case basis, based on the proposed design configuration.

8.2 Structural configuration

8.2.1 The scantlings and arrangements indicated are for twin hulled craft. Craft with a greater number of hulls will be specially considered on the basis of the Rules.

8.3 Structural continuity

8.3.1 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

8.3.2 Particular care is to be given to the continuity and alignment in way of the end connections of transverse bridging structures.

8.4 Cross-deck structure

8.4.1 For craft with multi-hulls linked by cross-deck structures, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

8.4.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

8.4.3 In the determination of the clearance, the following factors should be considered:
(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

8.4.4 The submitted clearances must be validated either by calculations according to accepted theories, model test, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

8.4.5 Where it is not possible to provide sufficient clearance to reduce the likelihood of slamming of the cross-deck structure, direct calculations or other appropriate means are to be used to assess the loads, assuming the most severe conditions for which the craft is to be approved.

8.5 Bulkheads

8.5.1 Longitudinal watertight bulkheads are to be arranged within the bridging structures of multi-hull craft to prevent cross flooding and the spread of smoke and flames in the event of fire. The number and distribution of bulkheads will be specially considered dependent upon the structural configuration and size of the craft but in no case is the number to be less than:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

8.6 Fore and aft ends

8.6.1 The forefoot and bow regions of fast craft that may be subjected to frequent impacts from flotsam are to be easily accessible for inspection. Access to the forepeak compartments may be provided through the forepeak bulkhead where access would otherwise be impracticable.

8.6.2 The aft end regions of all craft are to be easily accessible for inspections. Access may be provided through the aft peak bulkhead or by means of deck hatches or manholes.

8.7 Machinery spaces

8.7.1 Where an engine is fitted within a narrow hull, where engineroom temperatures may rise quickly, the ventilation requirements may require to be increased.

8.7.2 Within machinery spaces where space is limited access is to be provided for inspection.

8.8 Superstructures, deckhouses and bulwarks

8.8.1 Superstructures and deckhouses which enclose large flat open areas, that are subjected to racking loads and which may be of several tiers, are to be additionally stiffened with large web frames, partial bulkheads and pillars.

■ *Section 9* Navigation in ice

9.1 General

9.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require to be specially considered. The additional requirements for operation in ice will, in general, be in accordance with LR's *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships), Part 8, where appropriate, and also Pt 6, Ch 5,7, Pt 7, Ch 5,7 and Pt 8, Ch 5,6 for steel, aluminium and composite construction respectively.

9.1.2 It is the responsibility of the Owner to determine which ice class notation is most suitable for their requirements.

9.1.3 The strengthening requirements detailed in this Section are applicable to craft, other than those assigned the notation **HSC** and/or **LDC** (*see* Pt 1, Ch 2), intended for operation in first-year ice conditions.

9.1.4 For a multi-hull craft, special consideration is to be given to the interaction of the ice between the hulls.

9.1.5 The requirements of this Section assume that, when approaching ice-infested waters, the craft's speed will be reduced appropriately. The vertical extent of ice strengthening for craft intended to operate in ice conditions at speeds exceeding 15 knots will be specially considered.

9.2 Ice belt

9.2.1 Side scuttles are not to be situated in the ice belt.

9.2.2 If the weather deck in any part of the craft is situated below the upper limit of the ice belt, the bulwark is to be reinforced to the same degree as the shell plating in the main ice belt.

9.3 Stern construction

9.3.1 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midcraft region.

9.4 Bossings and shaft struts

9.4.1 For craft with two or more propellers, shafting and sterntubes are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

9.5 Powering of ice strengthened craft

9.5.1 For water jets, special consideration is to be given to the potential intake of ice pieces into the impeller causing additional loads and strengthening of steering buckets.

Section

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all the craft types detailed in the Rules, and requirements are given for rudders, nozzles, steering gear, bow and stern thrust unit structure and stabiliser structure.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than 0,7σ_T

where

σ_T = ultimate tensile strength of the material, in N/mm^2.

1.2.2 The scantlings in aluminium alloy are to be obtained by multiplying the scantlings in mild steel, determined from this Chapter, by the following factors:

(a) Plating thickness factor = k_{ta}
where $k_{ta} = \sqrt{k_{aa}}$

(b) Section modulus and cross sectional area factor, k_{aa}
where

k_{aa} = 235/σ_{ya} or 1,36, whichever is the greater

σ_{ya} = specified minimum yield stress or 0,2 per cent proof stress of aluminium alloy in the welded condition, in N/mm^2.

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Ch 2,9.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by Table 3.2.7.

2.1.2 For rudders having an increased diameter of rudder stock, *see* Fig. 3.2.1, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in diameter. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in Fig. 3.2.1, of double plate or single plate construction, constructed from steel, stainless steel or aluminium alloy. Other rudder types and materials will be subject to special consideration.

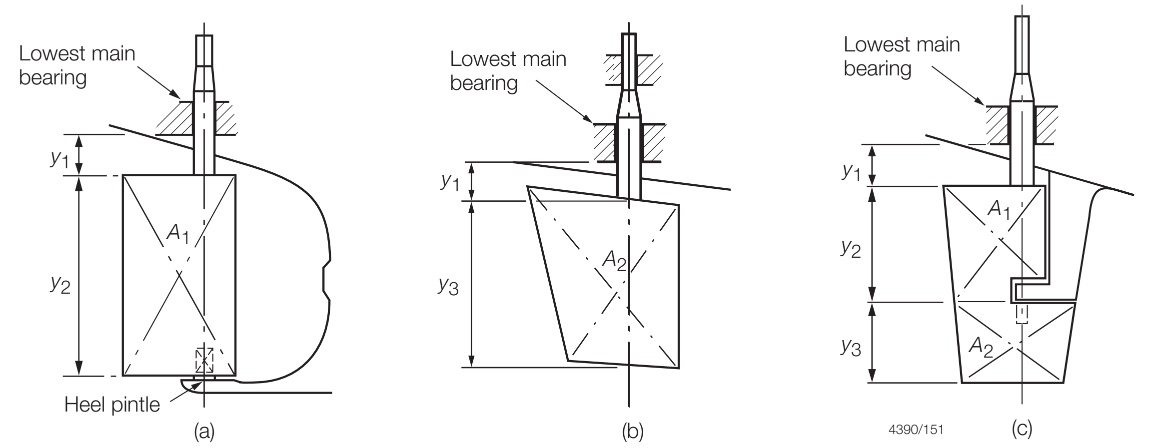


Fig. 3.2.1 Rudder types

2.6 Rudder profile coefficient f_R

2.6.1 The rudder profile coefficient f_R for use in Table 3.2.7 is to be as indicated in Table 3.2.1.

Table 3.2.1 Rudder profile coefficient f_R

Design criteria (*see* Fig. 3.2.2)	f_R ahead condition	f_R astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
High lift profile	1,7	To be specially considered
Symbols		
f_R = rudder profile coefficient for use in Table 3.2.7		
NOTE Where a rudder is behind a fixed nozzle, the value of f_R given above, is to be multiplied by 1,3.		

2.7 Rudder angle coefficient f_θ

2.7.1 The rudder angle coefficient, f_θ, for use in Table 3.2.7 is to be as indicated in Table 3.2.2.

Table 3.2.2 Rudder angle coefficient f_θ

Rudder angle	2 x 35°	2 x 45°
f_θ	1,0	1,23
Symbols		
f_θ = rudder coefficient for use in Table 3.2.7. Intermediate values may be obtained by interpolation		

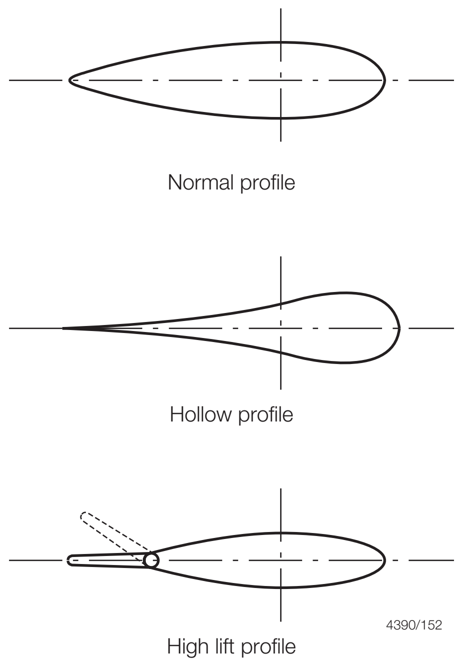


Fig. 3.2.2 Rudder profiles

2.8 Rudder position coefficient f_p

2.8.1 The rudder position coefficient, f_p, for use in Table 3.2.7 is to be as indicated in Table 3.2.3.

2.9 Rudder speed coefficient f_v

2.9.1 The rudder speed coefficient, f_v, for use in Table 3.2.7 is to be as indicated in Table 3.2.4.

Table 3.2.3 Rudder position coefficient f_p

Design criteria		f_p
Ahead condition	Rudder in propeller slipstream	0,248
	Rudder out of propeller slipstream	0,235
Astern condition		0,185
Bow rudder		0,226
Symbols		
f_p = rudder coefficient for use in Table 3.2.7		

Table 3.2.4 Rudder speed coefficient f_v

Design criteria	f_v
Craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3,0$	1,00
Craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3,0$	1,12 – 0,005V
Symbols	
L_{WL} as defined in Ch 1,6.2.5 V as defined in Table 3.2.7 f_v = rudder speed coefficient for use in Table 3.2.7	

2.10 Pintle arrangement coefficient *N*

2.10.1 The pintle arrangement coefficient, N, for use in Table 3.2.7 is to be as indicated in Table 3.2.5.

Table 3.2.5 Pintle arrangement coefficient *N*

Support arrangement	Value of N
Two or more pintles Upper stock	$N = 0$
One or no pintle	$N = A_1(0,67y_1 + 0,17y_2) - A_2(y_1 + 0,5y_3)$
Symbols	
N = coefficient for use in Table 3.2.7 A_1, A_2 = part rudder areas, in m^2, *see* Fig. 3.2.1 y_1, y_2, y_3 = vertical dimensions, in metres, *see* Fig. 3.2.1 Any values of y and A not indicated in Fig. 3.2.1 are to be taken as zero.	
NOTE If, in semi-spade (Mariner) type rudders, the pintle is housed above the rudder horn gudgeon and not as shown in Fig. 3.2.1(c), y_2 and y_3 are to be measured to the top of the gudgeon.	

2.11 Centre of pressure

2.11.1 The position of centre of pressure for use in Table 3.2.7 is to be as indicated in Table 3.2.6.

Table 3.2.6 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA} to be used in Table 3.2.7
Rectangular rudders; (a) Ahead condition (b) Astern condition	x_{PF} = $(0,33ex_B - x_L)$, but not less than $0,12x_B$ x_{PA} = $(x_A - 0,25x_B)$, but not less than $0,12x_B$
Non-rectangular rudders; (a) Ahead condition (b) Astern condition	x_{PF}, x_{PA}: as calculated from geometric form (*see* Note) but not less than: $\dfrac{0,12A_R}{y_R}$
Symbols	
x_{PF} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres x_{PA} = horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres x_B = breadth of rudder, in metres y_R = depth of rudder at centreline of stock, in metres A_R = rudder area, in m^2 x_L and x_A = horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres x_S = horizontal length of any rectangular strip of rudder geometric form, in metres e = hull form factor at ahead condition for $L < 65$ m, $e = 1,0$ for $L \geq 65$ m, $e = 2\left(C_b + 10\dfrac{B}{L_R} - 2\right)\dfrac{V}{\sqrt{L_R}}$ or $e = 1 + \left(\dfrac{L_R - 65}{70}\right)$ whichever is the lesser, but not less than 1,0 and need not be taken greater than 1,5 L_R, B and C_b are as defined Ch 1,6.2 V is as defined in Table 3.2.7	
NOTE For rectangular strips the centre of pressure is to be assumed to be located as follows: (a) $0,33ex_S$ abaft leading edge of strip for ahead condition. (b) $0,25x_S$ from aft edge of strip for astern condition.	

Table 3.2.7 Rudder stock diameter

Requirement
1. Basic stock diameter, d_s, at and below lowest bearing: $$d_s = f_c\, f_p\, f_v \sqrt[3]{\left(\frac{235}{\sigma_0}\right)^m f_R\, f_\theta\, (V+3)^2 \sqrt{A_R{}^2\, x_p{}^2 + N^2}}\ \text{mm}$$
2. Diameter in way of tiller, d_{SU}: $d_{SU} = d_s$ calculated from (1) with $N = 0$
3. Lateral force on rudder acting at centre of pressure of blade, P_L: $$P_L = \left(\frac{f_p}{0{,}248}\right)^3 \frac{(V+3)^2 A_R\, f_R\, f_\theta}{10}\ \text{kN}$$
Symbols
f_c = 79 for craft of Rule length, L_R, 50 m and below varying up to 83,3 at a Rule length, L_R, of 70 m. Intermediate values to be obtained by interpolation 83,3 for craft of Rule length, L_R, 70 m and above f_p = rudder position coefficient, *see* Table 3.2.3 f_v = rudder speed coefficient, *see* Table 3.2.4 f_R = rudder profile coefficient, *see* Table 3.2.1 f_θ = rudder angle coefficient, *see* Table 3.2.2 m = 0,75 for $\sigma_0 > 235$ = 1,0 for $\sigma_0 \leq 235$ σ_0 = minimum yield stress, in N/mm^2, of material used, and is not to be taken greater than $0{,}7\sigma_T$ σ_T = ultimate tensile strength of the material used, in N/mm^2 V = the maximum speed for the astern and ahead condition, in knots. In no case to be less than 5 knots A_R = rudder area, in m^2 x_P = x_{Pa} or x_{Pf}, for the astern and ahead condition respectively, *see* Table 3.2.6 N = coefficient dependent on rudder support arrangement, *see* Table 3.2.5
NOTE Where higher tensile steel is used for the rudder stock, σ_0 is not to be taken as greater than 450 N/mm^2.

2.12 Rudder stock (tubular)

2.12.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by Table 3.2.7, and can be calculated from the following formula:

$$d_E = \sqrt[3]{\frac{d_1{}^4 - d_2{}^4}{d_1}}\ \text{mm}$$

where

d_E = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm.

2.13 Single plate rudders

2.13.1 The scantlings of a single plate rudder are to be not less than required by Table 3.2.8, *see also* 2.5.1.

2.13.2 Rudder arms are to be efficiently attached to the mainpiece.

Table 3.2.8 Single plate rudder construction

Item	Requirement
Blade thickness	$t_B = 0{,}0015V\, y_W + 2{,}5$ mm with a minimum of 10 mm
Arms	Spacing ≤ 1000 mm $Z_A = 0{,}0005V^2\, x_a{}^2\, y_W$ cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to $0{,}75d_s$ mm
Symbols	
t_B = blade thickness, in mm y_W = vertical spacing of rudder arms, in mm V = maximum speed, in knots, as defined in Table 3.2.7 x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres Z_A = section modulus of arm, in cm^3	

2.14 Double plate rudders

2.14.1 The scantlings of a double plated rudder are to be not less than required by Table 3.2.9.

2.14.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.14.3 On semi-spade (Mariner) type rudders a notch effect in the corners in the bottom pintle region is to be avoided (*see* AA, Fig. 3.2.3). An insert plate, 1,6 times the Rule thickness of the side plating, is to be fitted at this position, extending aft of the main vertical web and having well rounded corners. The main vertical web is to be continuous over the full depth of the rudder and have a thickness not less than three times the thickness required by Table 3.2.9, Item (5). Where an additional continuous main vertical web is arranged to form an efficient box structure, the webs are to have a thickness not less than required by Table 3.2.9, Item (5).

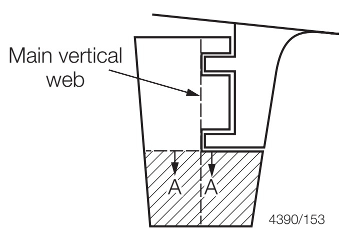


Fig. 3.2.3 Semi-spade (mariner) type rudder

2.14.4 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required, and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

Table 3.2.9 Double plated rudder construction

Item	Requirement
(1) Side plating	$t = \beta\ F_a\ (0{,}003y_w + 2{,}03)(1{,}45 + 0{,}1\ \sqrt{d_s}\ )$ mm
(2) Webs - vertical and horizontal	As (1) above
(3) Top and bottom plates	As (1) above using y_w = maximum rudder width, in mm, at top or bottom, but not less than 900 mm
(4) Nose plates	$t_N \geq 1{,}25t$ from (1) above
(5) Mainpiece – fabricated rectangular	Breadth and width $\geq d_s$ $t_M = F_a\ (8{,}5 + 0{,}56\ \sqrt{d_s}\ )$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending $\leq$ 78,0 N/mm^2
(6) Mainpiece – tubular	Inside diameter $\geq d_s$ t_M as for (5) above Side plating as for (1) above Bending stress as for (5) above
Symbols	
β = $A_a\ (1 - 0{,}25A_a)$ A_a = panel aspect ratio, but is not to be taken as greater than 2,0 F_a = 1,0 for mild steel, 0,95 for aluminium alloy and 0,9 for stainless steel. Other materials will be specially considered t = thickness, in mm y_w = vertical spacing, in mm, of the horizontal webs or arms, but is not to exceed 900 mm d_s = basic stock diameter, given by Table 3.2.7, in mm t_N = thickness, in mm, of nose plate t_M = thickness, in mm, of side plating and vertical webs forming mainpiece x_B = breadth of rudder, in metres, on centreline of stock	

2.14.5 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds onto flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.14.6 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.14.7 Where the fabricated mainpiece of a spade rudder is connected to the horizontal coupling flange by welding, a full penetration weld is required.

2.15 Cast metal rudders

2.15.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.16 Lowest main bearing requirement

2.16.1 The design of the lowest bearing is to comply with the requirements of Table 3.2.10.

2.17 Bearings

2.17.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.17.2 Where it is proposed to use stainless steel for liners or bearings for rudder stocks and/or pintles, the chemical composition is to be submitted for approval. Where the two surfaces are stainless steel materials, they should have suitable resistance to galling. When stainless steel material is used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided to protect against stagnant sea-water initiated corrosion.

2.17.3 Synthetic rudder bearing materials are to be of a type approved by LR.

2.18 Liners

2.18.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

2.18.2 Where it is proposed to use stainless steel liners, the requirements in 2.17.2 are to be complied with.

2.18.3 When stainless steel liners are used, arrangements to ensure an adequate supply of sea-water to the liner are to be provided.

Table 3.2.10 Lowest main bearing requirements

Item	Requirement	
Lowest main bearing	Depth Z_B, in mm $1,5d_s \geq Z_B \geq 1,0d_s$	Minimum thickness of wall, in mm lesser of $0,2d_s$ or 100
Bearing pressure (on the projected area of the lowest main bearing), where the projected area is to be taken as the length x diameter	Bearing material	Maximum pressure, in N/mm^2 *see* Note 4
	Metal Synthetic	7,0 5,5
Clearance in lowest main bearing on the diameter (note should be taken of the manufacturer's recommended clearances, particularly where bush material requires pre-soaking)	Bearing material	Minimum clearance, in mm *see* Note 3
	Metal, *see* Note 2 Synthetic	$0,001d_s + 1,0$ $0,002d_s + 1,0$ but not less than 1,5
Symbols		
d_s = stock diameter, given by Table 3.2.7, in mm		

NOTES
1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered.
2. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained.
3. Value of proposed minimum clearance is to be indicated on plans submitted for approval.
4. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

2.19 Pintles

2.19.1 Rudder pintles and their bearings are to comply with the requirements of Table 3.2.11.

2.19.2 Where the lower pintle is housed above the rudder gudgeon, *see* Fig. 3.2.4, and not below as shown in Fig. 3.2.5, C_{PL} is to be measured to the top of the gudgeon.

2.19.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in Table 3.2.11.

2.19.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

2.19.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.19.6 The bottom pintle on semi-spade (Mariner) type rudders are:
(a) If inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or
(b) If inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

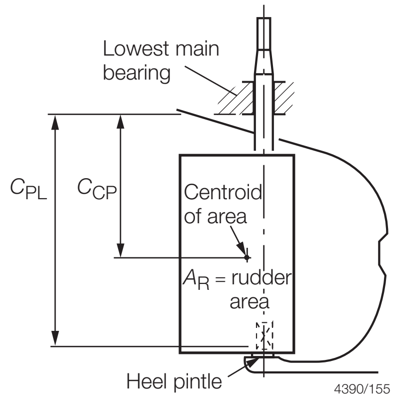


Fig. 3.2.4
Lower pintle housed above rudder gudgeon

2.19.7 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* 2.37.

2.19.8 Where it is proposed to use stainless steel liners, the requirements in 2.17.2 are to be complied with.

Table 3.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$\delta_{PL} = \sqrt{\left(\dfrac{235}{\sigma_o}\right)^m} (31 + 4{,}17V\sqrt{A_{PL}})$ mm For single pintle rudders and lower pintle of semi-spade rudders: $A_{PL} = \dfrac{A_R C_{CP}}{C_{PL}}$ m^2 but for semi-spade rudders need not be taken greater than A_R Upper pintle on semi-spade rudders; $A_{PL} = A_R\left(1 - \dfrac{C_{CP}}{C_{PL}}\right)$ m^2 or $0{,}35A_R$ m^2, whichever is the greater For rudders with two or more pintles (except semi-spade rudders): $A_{PL} = \dfrac{A_R}{N_{PL}}$ m^2	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200mm diameter)	1 in 6
	Manual assembly, key fitted (pintle ≥ 400mm diameter)	1 in 9
	For keyed and other manually assembled pintles with diameters between 200 mm and 400 mm, the taper is to be obtained by interpolation	
	Hydraulic assembly, dry fit Hydraulic assembly, oil injection	1 in 12 1 in 15
(3) Bearing length	$Z_{PB} \geq 1{,}2\delta_{PL}$ mm May be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must not be less than $1{,}0\delta_{PL}$ mm	
(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal Synthetic	7,0 N/mm^2 5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \dfrac{A_{PL}(V+3)^2 f_R}{10}$ kN A_{PL} as for item (1)	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}5\delta_{PL}$ but need not normally exceed 125mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval	Bearing material	Minimum clearance, mm
	Metal Synthetic	$0{,}001\delta_{PL} + 1{,}0$ $0{,}002\delta_{PL} + 1{,}0$ but not less than 1,5

Symbols

δ_{PL} = pintle diameter, in mm
V = as defined in Table 3.2.7 but not less than 10 knots
A_{PL} = rudder area supported by the pintle, in m^2
C_{CP}, C_{PL} = dimensions in metres, as indicated in Figs. 3.2.4 and 3.2.5
A_R = rudder area, in m^2
σ_o = as defined in Table 3.2.7
N_{PL} = number of pintles on the rudder
Z_{PB} = pintle bearing length, in mm
P_{PL} = force acting on bearing, in kN
b_G = thickness of gudgeon material in way of pintle, in mm
f_R = rudder profile coefficient, *see* Table 3.2.1
m = as defined in Table 3.2.7

NOTE
Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

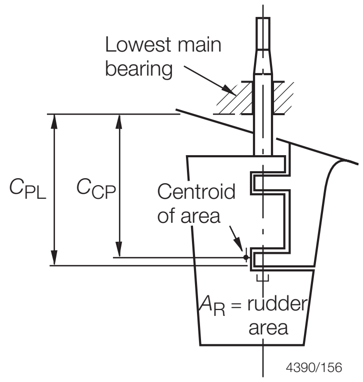


Fig. 3.2.5
Lower pintle housed below rudder gudgeon

2.20 Bolted couplings

2.20.1 Rudder coupling design is to be in accordance with Table 3.2.12.

2.20.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.20.3 For rudders with horizontal coupling arrangements, where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

Table 3.2.12 **Rudder couplings to stock** (*see continuation*)

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling
(1) Bolted couplings (*see* Notes)	n	≥ 6	≥ 8
	δ_b	$\dfrac{0,65 d_s}{\sqrt{n}}$	$\dfrac{0,81 d_s}{\sqrt{n}}$
	m	$0,00071 n\, d_s\, \delta_b^2$	$0,00043 d_s^3$
	t_f	$\geq \delta_b$, *see* Note 1	δ_b
	α_{max} *see* Note 2	$(53,82 - 35,29 k_1) \dfrac{d_s^3}{P_L\, h 10^6} - \left(1,8 - 6,3 \dfrac{R}{d_s}\right) \dfrac{t_f - t_{fa}}{t_{fa}}$	—
	$\alpha_{as\ built}$ *see* Note 2	$\leq \alpha_{max}$	—
	w_f	$0,67 \delta_b$	$0,67 \delta_b$
(2) Conical couplings	θ_t	$\leq \dfrac{1}{K_1}$	
	l_t	$\geq 1,5 d_s$	
	$\overline{p}$	$\dfrac{P_R\, \theta_t\, \overline{\delta}_{ST} + 4 M_T \sqrt{K_2 \left(\left(\dfrac{P_R\, \overline{\delta}_{ST}}{2 M_T} \right)^2 + 1 \right) - \left(\dfrac{\theta_t}{2} \right)^2}}{5,66 \overline{\delta}_{ST}^2\, l_t \left(K_2 - \left(\dfrac{\theta_t}{2} \right)^2 \right)}$	
	w	$\dfrac{9,6 \times 10^{-6}\, \overline{p}\, \overline{\delta}_{ST}}{\theta_t (1 - \overline{f}^2)}$	
	P_u	Approximately equal to $2,83\, \overline{p}\, l_t\, \overline{\delta}_{ST} \left(K_3 + \dfrac{\theta_t}{2} \right)$	
	P_o	Approximately equal to $2,83\, \overline{p}\, l_t\, \overline{\delta}_{ST} \left(K_3 - \dfrac{\theta_t}{2} \right)$	
	σ_o	$\geq \dfrac{12,35 \times 10^4\, w\, \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$	

Table 3.2.12 Rudder couplings to stock (*see continuation*)

<table>
<tr><th rowspan="2">Arrangement</th><th rowspan="2">Parameter</th><th colspan="2">Requirement</th></tr>
<tr><th>Horizontal coupling</th><th>Vertical coupling</th></tr>
<tr><td rowspan="8">(1) Bolted couplings
(see Notes)</td><td>n</td><td>≥ 6</td><td>≥ 8</td></tr>
<tr><td>δ_b</td><td>$\dfrac{0{,}65 d_s}{\sqrt{n}}$</td><td>$\dfrac{0{,}81 d_s}{\sqrt{n}}$</td></tr>
<tr><td>m</td><td>$0{,}00071 n \, d_s \, \delta_b^2$</td><td>$0{,}00043 d_s^3$</td></tr>
<tr><td>t_f</td><td>$\geq \delta_b$, see Note 1</td><td>δ_b</td></tr>
<tr><td>α_{max}
see Note 2</td><td>$(53{,}82 - 35{,}29 k_1) \dfrac{d_s^3}{P_L \, h 10^6} - \left(1{,}8 - 6{,}3 \dfrac{R}{d_s}\right) \dfrac{t_f - t_{fa}}{t_{fa}}$</td><td>—</td></tr>
<tr><td>$\alpha_{as\ built}$
see Note 2</td><td>$\leq \alpha_{max}$</td><td>—</td></tr>
<tr><td>w_f</td><td>$0{,}67\delta_b$</td><td>$0{,}67\delta_b$</td></tr>
<tr><td rowspan="8">(2) Conical couplings</td><td>θ_t</td><td colspan="2">$\leq \dfrac{1}{K_1}$</td></tr>
<tr><td>l_t</td><td colspan="2">$\geq 1{,}5 d_s$</td></tr>
<tr><td>$\overline{p}$</td><td colspan="2">$\dfrac{P_R \, \theta_t \, \overline{\delta}_{ST} + 4M_T \sqrt{K_2 \left(\left(\dfrac{P_R \, \overline{\delta}_{ST}}{2M_T} \right)^2 + 1 \right) - \left(\dfrac{\theta_t}{2} \right)^2}}{5{,}66 \overline{\delta}_{ST}^2 \, l_t \left(K_2 - \left(\dfrac{\theta_t}{2} \right)^2 \right)}$</td></tr>
<tr><td>w</td><td colspan="2">$\dfrac{9{,}6 \times 10^{-6} \, \overline{p} \, \overline{\delta}_{ST}}{\theta_t \, (1 - \overline{f}^2)}$</td></tr>
<tr><td>P_u</td><td colspan="2">Approximately equal to $2{,}83 \, \overline{p} \, l_t \, \overline{\delta}_{ST} \left(K_3 + \dfrac{\theta_t}{2} \right)$</td></tr>
<tr><td>P_o</td><td colspan="2">Approximately equal to $2{,}83 \, \overline{p} \, l_t \, \overline{\delta}_{ST} \left(K_3 - \dfrac{\theta_t}{2} \right)$</td></tr>
<tr><td>σ_o</td><td colspan="2">$\geq \dfrac{12{,}35 \times 10^4 \, w \, \theta_t \sqrt{3 + f^4}}{\delta_{ST}}$</td></tr>
</table>

2.20.4 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, R, *see* Fig. 3.2.6(a). The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.20.5 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see* Fig. 3.2.6(b).

2.21 Conical couplings

2.21.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved, and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked, and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After the final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.21.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After the final fitting of the stock to the rudder, positive means are to be used for locking this nut.

Table 3.2.12 Rudder couplings to stock (*conclusion*)

Symbols

n = number of bolts in coupling

δ_b = diameter of coupling bolts, in mm

d_s, d_{su} = rudder stock diameter as defined in Table 3.2.7

m = first moment of area of bolts about centre of coupling, in cm^3

k_1 = the greater of k_s and k_f

k_s = $\left(\dfrac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the rudder stock and m is as defined in Table 3.2.7

k_f = $\left(\dfrac{235}{\sigma_o}\right)^m$ where σ_o is the specified minimum yield stress at the upper coupling flange and m is as defined in Table 3.2.7

h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see* Fig. 3.2.6(a)

R = palm radius between rudder stock and connected flange, not smaller than $\dfrac{d_s}{10}$, in mm

t_f = minimum thickness of coupling flange, in mm

t_{fa} = as built flange thickness, in mm

α_{max} = maximum allowable stress concentration factor

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$$= \frac{0{,}73}{\sqrt{\left(\dfrac{R}{d_s}\right)}}$$

w_f = width of flange material outside the bolt holes, in mm

θ_t = taper of conical coupling, on the diameter, e.g.:

$$\theta_t = \frac{1}{15} = 0{,}067$$

l_t = length of taper, in mm

$\bar{p}$ = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

P_u, P_o = corresponding push-up, pull-off loads respectively, in N

σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70 per cent of the ultimate tensile strength

P_R = effective weight of rudder, in N

$\bar{\delta}_{ST}$ = mean diameter of coupling taper, in mm

δ_{ST} = diameter of coupling taper at any position, in mm

$\bar{\delta}_{GH}$ = mean external diameter of gudgeon housing, in mm

δ_{GH} = external diameter of gudgeon housing at any position, in mm

$\bar{f}$ $\dfrac{\bar{\delta}_{ST}}{\bar{\delta}_{GH}}$

f $\dfrac{\delta_{ST}}{\delta_{GH}}$

M_T = maximum torque applied to stock, and is to be taken as the greater of M_F, M_A or M_W

M_F = $P_L\ X_{PF}$ x 10^6 Nmm in the ahead condition

M_A = $P_L\ X_{PA}$ x 10^6 Nmm in the astern condition

M_W = the torque generated by the steering gear at the maximum working pressure supplied by the manufacturer, in Nmm. M_W is not to exceed the greater of $3{,}0M_F$ or $3{,}0M_A$

P_L = lateral force on rudder acting at centre of pressure in ahead and astern conditions, as defined in Table 3.2.7, in kN

X_{PF}, X_{PA} = the horizontal distances, in metres, *see* Table 3.2.6

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
	without key	15	0,0036	0,025
Dry fit method	with key	12	0,0128	0,170
	without key	12	0,0072	0,170

NOTES
1. For spade rudders with horizontal coupling, t_f is not to be less than $0{,}25d_s$.
2. This requirement is applicable only for spade rudders with horizontal couplings, *see* Fig. 3.2.6.
3. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.

2.22 Rudder carrier arrangements

2.22.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.23 Anti-jump collars

2.23.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.23.2 Jumping collars are not to be welded to the rudder stock.

2.24 Drain plugs

2.24.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

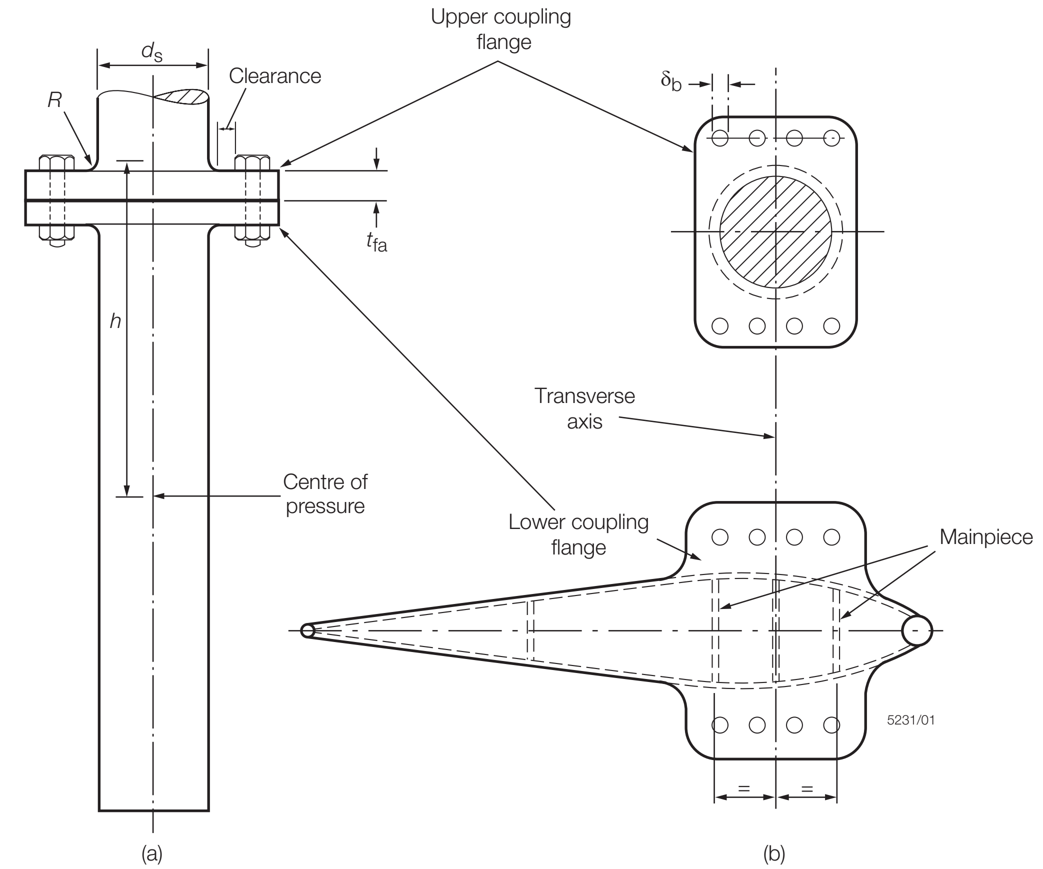


Fig. 3.2.6 Rudder stock connection

2.25 Corrosion protection

2.25.1 All metalwork, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.25.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means are to be employed for this purpose.

2.26 Dissimilar materials

2.26.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see* Table 3.2.7.

2.27 Internal coatings

2.27.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted.

2.28 Pressure testing

2.28.1 For testing of rudders, *see* Table 1.7.1 in Chapter 1.

2.29 Tiller arms, quadrants

2.29.1 Tillers and quadrants are to comply with the requirements of Table 1.4.1 in Pt 14, Ch 1.

2.29.2 The steering gear is to be mounted on a seat and adequately secured.

2.30 Connecting bars

2.30.1 Connecting bars are to comply with the requirements of Pt 14, Ch 1,4.3.3.

2.31 Keys and keyways

2.31.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0{,}25 d_{SU}^2$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{SU}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{SU} is as defined in Table 3.2.7.

2.31.2 Keyways are to extend over the full depth of the tiller boss.

2.31.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.32 Stopping arrangements

2.32.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.33 Novel designs

2.33.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively the Builder's/designer's calculations are to be submitted for consideration.

2.34 FRP double plated rudders

2.34.1 Fibre reinforced plastic rudders are to incorporate a metallic framework, consisting of a mainpiece fitted with arms, within the blade, or an equivalent arrangement. Where rudder blades are moulded in halves they are to be effectively joined together by means of external overbonding of the joint or suitable mechanical fastening or equivalent. Both halves of the rudder blade moulding are to be effectively connected to the metallic framework and mainpiece by either mechanical means or suitable bonded connection.

2.34.2 Rudders are to be filled with a suitable material upon completion of the join up, details of the filler material are to be submitted.

2.34.3 The diameter of the top of the rudder mainpiece must not be less than that of the rudder stock. For spade rudders this diameter may be gradually reduced for the lower third to not less than 75 per cent of the rudder stock diameter.

2.34.4 The rudder arms are to be efficiently attached to the mainpiece.

2.34.5 The laminate weight of moulded fibre reinforced plastics double plate rudders is to be determined by direct calculation, subject to a minimum laminate thickness of 5 mm.

2.35 Rudder tube arrangements

2.35.1 The rudder tube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

2.35.2 The scantlings of rudder tubes will be individually considered.

2.35.3 For steel and aluminium hulls, the bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.35.4 For F.R.P. hulls, the bottom shell laminate in way of the rudder tubes is to be locally increased by 50 per cent. The increased thickness in way of the rudder tube need not exceed the rule keel thickness requirement.

2.35.5 For F.R.P. sandwich hulls the shell in way of the rudder tube connection is to be either:

(a) Reduced from the sandwich hull construction to single skin laminate for a distance of a least three times the rudder tube diameter about the rudder stock axis. The single skin region is to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate subject to this being at least equivalent to a 50 per cent increase in thickness of the Rule minimum bottom shell laminate for a single skin F.R.P. craft of the equivalent Rule length, L_R. The reinforced laminate need not be greater than the Rule keel laminate thickness.

(b) Reduced from the sandwich hull construction to a single skin laminate for a distance of three times the rudder tube diameter about the rudder stock axis. After bonding in the rudder tube to the single skin laminate the foam core and inner skin are then reinstated.

(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

2.35.6 The rudder tube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

2.35.7 When bonding in rudder tubes the bonding angle is to be not less than the Rule minimum bottom shell weight. F.R.P. tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation.

2.35.8 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.35.9 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.35.10 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.35.11 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

2.36 Watertight gland

2.36.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline, to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.36.2 Where the top of the rudder tube is significantly higher than the deepest load waterline a lesser arrangement of watertightness, such as 'O' rings may be accepted.

2.36.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube. The gland packing being retained against the top bearing or a check in the wall of the rudder tube and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.36.4 Alternative arrangements utilising lip seals or 'O' rings, either in isolation or in combination with one or other of the alternative seal arrangements, will be the subject of special consideration.

2.37 In-water Survey requirements

2.37.1 Where an ***IWS** (In-water Survey) notation is to be assigned, *see* Pt 1, Ch 2,3.8, means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the craft afloat.

■ *Section 3* Sternframes and appendages

3.1 General

3.1.1 Stern frames, rudder horns and boss end brackets may be constructed of cast or forged steel, cast or forged aluminium alloy, fabricated from aluminium or steel plate or moulded from fibre reinforced plastic dependent upon the material of construction of the craft. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel or aluminium alloy as applicable to the material of construction of the main hull.

3.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

3.1.3 Castings and forgings are to comply with the requirements of Chapters 4 and 5 of the Rules for Materials.

3.1.4 Sternframes, rudder horns, shaft brackets, etc., are to be effectively integrated into the craft structure, and their design is to be such as to facilitate this.

3.2 Sternframes

3.2.1 The scantlings of sternframes are to be determined from Table 3.3.1. In the case of very large craft, the scantlings and arrangements may be required to be verified by direct calculations.

3.2.2 Fabricated and cast propeller posts and rudder posts of twin screw craft are to be strengthened at intervals by webs. In way of the upper part of the sternframe arch, these webs are to line up with the floors.

3.2.3 Rudder posts and propeller posts are to be connected to floors of increased thickness. *See* Ch 3,5.10 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.2.4 The requirements for sternframes of composite craft are to be in accordance with Pt 8, Ch 3,5.9.

3.3 Rudder horns

3.3.1 The requirements for the scantlings and arrangements of rudder horns are given in Ch 3,5.9 of Parts 6 and 7 for steel and aluminium alloy construction and Pt 8, Ch 3,5.8 for composite construction respectively.

3.4 Shaft bossing

3.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the craft's internal structure.

3.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

3.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the craft. The arms are to be strengthened at intervals by webs.

3.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.4.5 The scantlings of supports will be specially considered. In the case of certain high powered craft, direct calculations may be required.

Table 3.3.1 Sternframes (*see continuation*)

Item	Parameter	Requirement		
(1) Propeller posts		Cast steel (*see* Fig. 3.3.1(a))	Forged Steel (*see* Fig. 3.3.1(b))	Fabricated mild steel (*see* Fig. 3.3.1(c))
	l	$165\sqrt{T}$ mm	–	$200\sqrt{T}$ mm
	r	$20\sqrt{T}$ mm	–	$18\sqrt{T}$ mm
	t_W	$8\sqrt{T}$ mm (need not exceed 38 mm) (*see* Notes 1 and 2)	–	$6\sqrt{T}$ mm (need not exceed 30 mm) (*see* Notes 1 and 2)
	t_1	$12\sqrt{T}$ mm (min 19 mm)	–	$12\sqrt{T}$ mm
	t_2	$16\sqrt{T}$ mm (min 25 mm)	–	–
	W	$115\sqrt{T}$ mm	$40\sqrt{T}$ mm	$140\sqrt{T}$ mm
	A	–	$(10 + 0{,}5L_R)T$ cm^2 where $L_R \leq 60$ m $40T$ cm^2 where $L_R > 60$m	–
(2) Propeller boss (*see* Note 3 and Fig. 3.3.2)	t_b	$(0{,}1\delta_{TS} + 56)$ mm, but need not exceed $0{,}3\delta_{TS}$		
(3) Rudder posts or axles		Single screw with integral solepiece, *see* Fig. 3.3.5 (a)	Single screw with bolted rudder axle, with hull, *see* Fig. 3.3.3	Twin screw, integral *see* Fig. 3.3.4
	n	–	6 (*see* Note 4)	–
	r	–	–	$20\sqrt{T}$ mm
	r_b	–	δ_A mm	–
	t_F	–	δ_b mm	–
	t_1	–	–	$12\sqrt{T}$ mm
	t_2	–	–	$15\sqrt{T}$ mm
	t_3	–	–	$18\sqrt{T}$ mm
	w	–	–	$120\sqrt{T}$ mm
	z_{PB1}, z_{PB2}	–	$1{,}2\delta_{PL2}$ mm	–
	Z_T	$0{,}147A_R\, b(V + 3)^2$ cm^3	–	–
	δ_A	–	$(25T + 76)$ mm but need not exceed $0{,}9\delta_{PL2}$ mm	–
	δ_b	–	$6{,}25T + 19$ mm or $0{,}225\delta_{PL2}$ mm whichever is the greater	–
	$\delta_{PL1}, \delta_{PL2}$ bearing pressure and pintle clearance	–	As for rudder pintles (*see* Table 3.2.11)	–
(4) Solepieces (*see* Notes 5,6 and 7)		With integral rudder post, *see* Fig. 3.3.5(a)	With bolted axle, *see* Fig. 3.3.5(b)	Open type (no rudder post), *see* Fig. 3.3.5(c)
(a) Cast steel	Z_T	$0{,}50W$ cm^3	$0{,}95W$ cm^3	$1{,}00W$ cm^3
	Z_V	$0{,}35W$ cm^3	$0{,}40W$ cm^3	$0{,}50W$ cm^3
(b) Fabricated mild steel	Z_T	$0{,}42W$ cm^3	$0{,}81W$ cm^3	$0{,}85W$ cm^3

Table 3.3.1 Sternframes (*conclusion*)

Symbols	
L_R, T as defined in Ch1,6.2	$L_1 = L_R$, but is to be taken not less than 90 m
a,b,c = distances, in metres, as shown in Fig. 3.3.5	V = maximum service speed, in knots, with the craft in the loaded condition
n = number of bolts in palm coupling	$W = \dfrac{400 A_R\, C\,(V+3)^2\,(3x+a)}{b\,(L_1+640)}$
r_b = mean distance of bolt centres from centre of palm, in mm	Z_T = section modulus against transverse bending, in cm^3
t_b = finished thickness of boss, in mm	Z_V = section modulus against vertical bending, in cm^3
x = distance, in metres, from centre of rudder stock to section under consideration	δ_b = diameter of coupling bolts, in mm
A = cross-sectional area of forged steel propeller post, in cm^2	δ_{TS} = diameter of tail shaft, in mm
A_R = total rudder area, in m^2	

NOTES
1. Where scantlings and proportions of the propeller post differ from those shown in Item 1, the section modulus about the longitudinal axis of the proposed section normal to the post is to be equivalent to that with Rule scantlings. t_1 is to be not less than $8\sqrt{T}$ (minimum of 19 mm for cast steel sternframes)
2. On sternframes without solepieces, the modulus of the post below the propeller boss, about the longitudinal axis may be gradually reduced to not less than 85% of that required by Note 1, subject to the same thickness limitations.
3. In fabricated sternframes the connection of the propeller post to the boss is to be by full penetration welds.
4. If more than six bolts are fitted, the arrangements are to provide equivalent strength.
5. In fabricated solepieces, transverse webs are to be fitted spaced not more than 760 mm apart. Where the breadth of the solepiece exceeds 900 mm, a centreline vertical web is also to be fitted.
6. Solepieces supporting fixed or movable nozzles will be specially considered (*see* 4.2).
7. For dredging and reclamation craft in restricted service Groups G1, G2 or G3, the scantlings of an 'open' type solepiece are to be such that:
   (a) Z_T = 0,625W cm^3.
   (b) The cross-sectional area is not less than 18 cm^2.
   (c) The depth is not less than two-thirds of the width at any point.

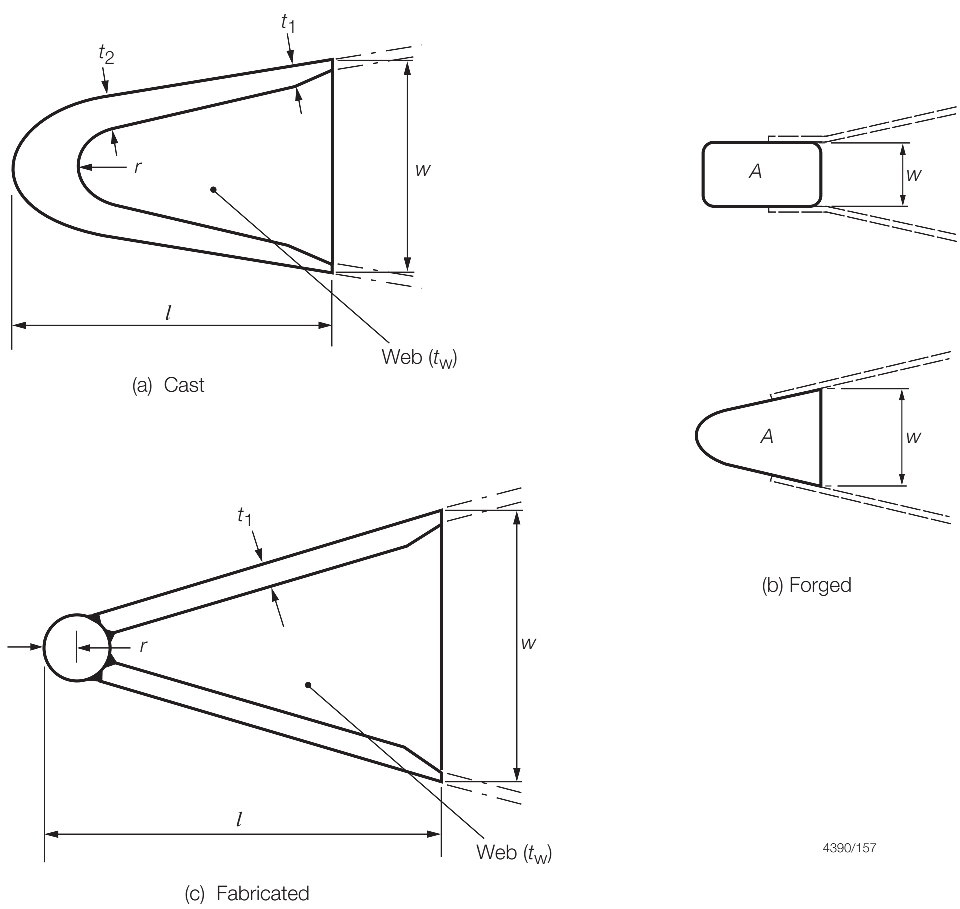


Fig. 3.3.1 Propeller posts

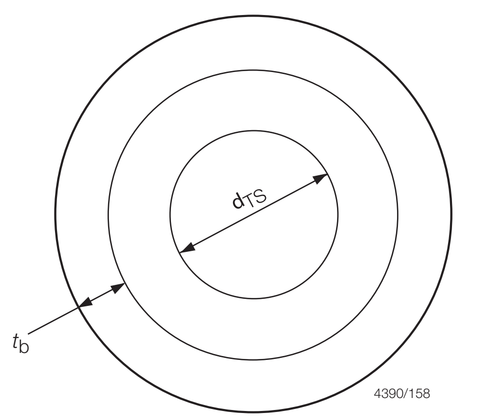


Fig. 3.3.2 Propeller boss

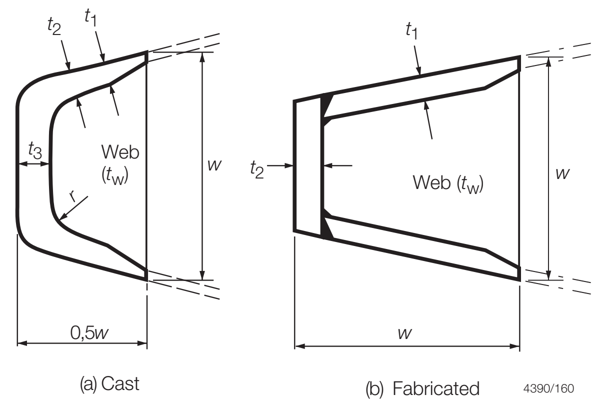


Fig. 3.3.4 Rudder post for twin screw craft

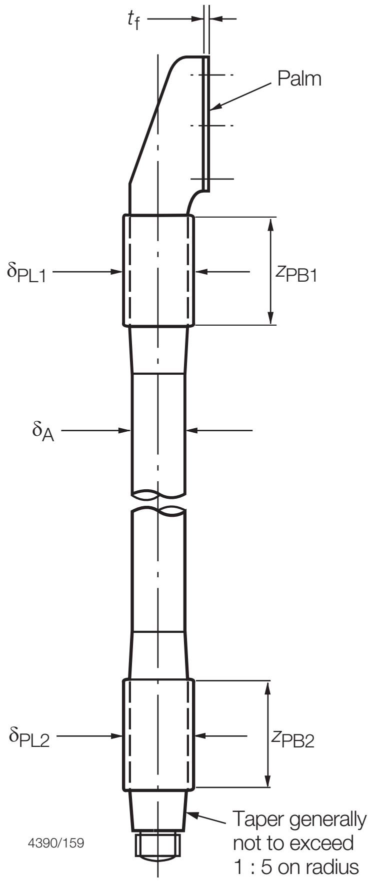


Fig. 3.3.3 Rudder axle

3.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

3.5 Shaft brackets

3.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from 3.6.1 and 3.7.2.

3.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small craft the use of single arm brackets will be considered.

3.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.5.4 Where bracket arms are carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

3.5.5 In the case of certain high powered craft direct calculations may be required.

3.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in 3.5.1.

3.5.7 The length of the shaft bracket boss, l_b, is to be sufficient to support the length of the required bearing. In general l_b is not to be less than $4d_t$, where d_t is the Rule diameter of the screwshaft, in mm, *see* Pt 11, Ch 2,4.4. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, *see* Pt 11, Ch 2,4.16.2. However in no case is l_b to be less than the greater of:

(a) $2d_t$; or
(b) that recommended by the bearing manufacturer; or
(c) as required by 3.4.2.

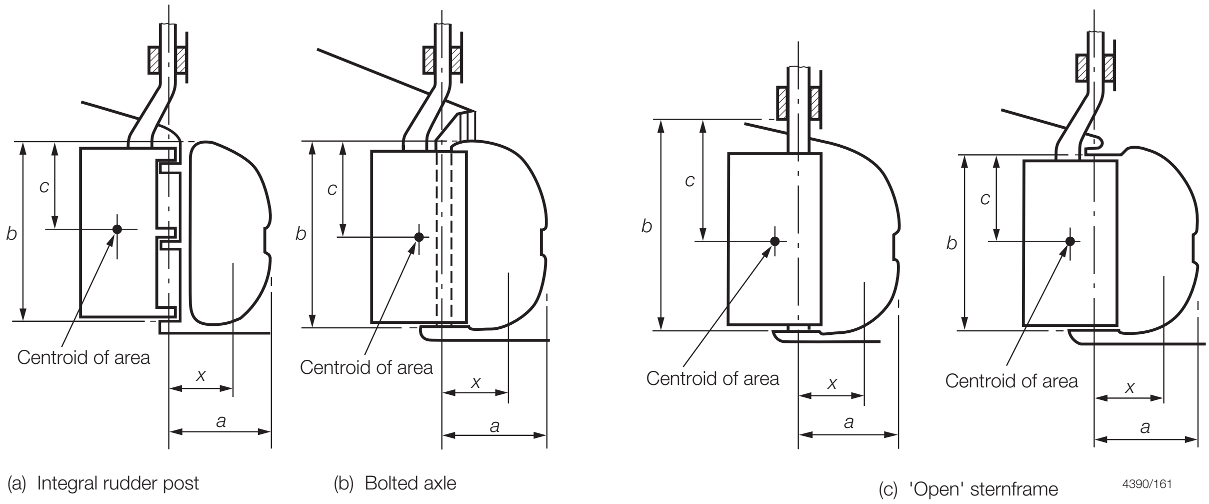


Fig. 3.3.5 Solepiece

3.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than $d_t/4$. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b, is to be not less than:

$$t_b = 0{,}75 d_t \left(\sqrt[3]{f_1} - 0{,}667\right) \text{ mm}$$

NOTE:
In no case is t_b to be taken as less than 12 mm.

where

d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm, *see* Pt 11, Ch 2,4

f_1 = σ_S/σ_B but not less than 0,825

σ_S = ultimate tensile strength of the shaft material, in N/mm^2

σ_B = ultimate tensile strength of the boss material, in N/mm^2.

3.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is outwith the scope of classification.

3.6 Single arm shaft brackets ('P' – brackets)

3.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s\, d_t^2\, f}{45000} \text{ cm}^3$$

where

a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see* Fig. 3.3.6

d_t = the Rule diameter for an unprotected screwshaft, in mm, as given in Pt 11, Ch 2,4, using A = 1,0

f = $400/\sigma_u$

σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

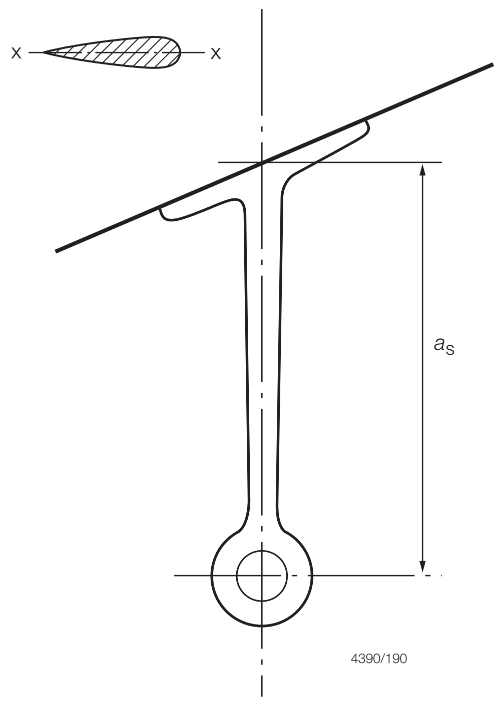


Fig. 3.3.6 Single arm shaft bracket

3.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

3.7 Double arm shaft brackets ('A' – brackets)

3.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

3.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0{,}45\, n^3 \quad \text{cm}^3$$

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_t \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(\frac{0{,}0112}{f}\right)\left(\frac{a_d}{d_t}\right)^2\right)}\right)} \quad \text{cm}$$

a_d = the length of the longer strut, in mm, *see* Fig. 3.3.7

d_t and f are as given in 3.6.1.

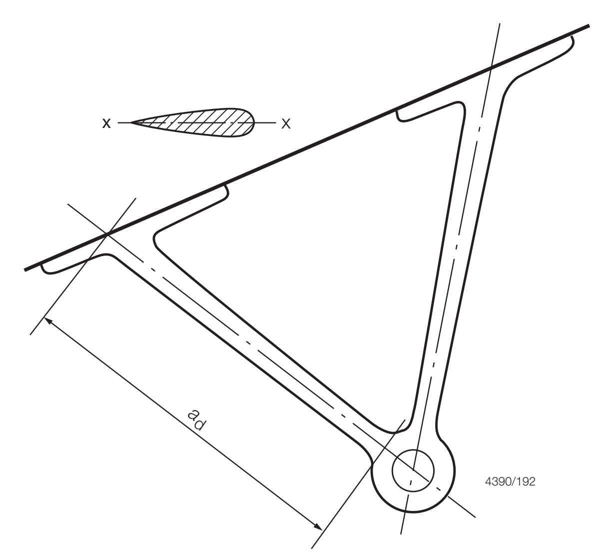


Fig. 3.3.7 Double arm shaft bracket

3.8 Intermediate shaft brackets

3.8.1 The length and thickness of the shaft bracket boss are to be as required by 3.5.7 or 3.5.8 as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

3.9 Attachment of shaft brackets by welding

3.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the craft is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

3.10 Attachment of shaft brackets by bolting

3.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates, or reinforced shell laminate in FRP craft, are to be additionally supported by substantial floor plates or other structure.

3.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

3.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

3.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

3.10.5 The minimum thickness of a resin chock is to be 12 mm.

3.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from 3.5.7 or 3.5.8 as appropriate.

3.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt{\frac{Z_{xx}}{8{,}75\,\pi\, n\, h \times 10^{-5}}} \quad \text{mm}$$

and not less than the shell plate thickness in way of the palm or 12 mm, whichever is greater

where

Z_{xx} = the section modulus of the bracket arm determined from 3.6.1 or 3.7.2, in cm^3, as appropriate
n = the number of bolts in each row
h = the distance between rows of bolts, in mm
d_b = the bolt diameter in the same material as the propeller bracket, in mm.

3.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from 3.10.7, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

3.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

3.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness $t_b/6$ mm, subject to a minimum of 3 mm.

3.11 Attachment of shaft brackets by bonding

3.11.1 Proposals to connect shaft brackets to FRP hulls by bonding will be the subject of special consideration. Details of the following are to be submitted:

(a) Preparation of the hull penetration and internal bonding surface.
(b) Details of transverse through pinning of the shaft bracket strut.
(c) Details of over bonding of strut and pin arrangement and subsequent integration of strut into primary hull structure.

3.12 Alignment of shaft brackets

3.12.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

3.12.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type. *See* 3.10.2 and 3.10.3.

3.12.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and stern tube.

3.13 Sterntubes

3.13.1 The sterntube construction may be of aluminium alloy, steel, bronze or fibre reinforced plastic.

3.13.2 The sterntube scantlings are to be individually considered.

3.13.3 For steel and aluminium hulls, the bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

3.13.4 For FRP hulls, the bottom shell laminate, in way of the sterntube, is to be locally increased by 50 per cent by gradual tapering of the laminate. The increased thickness in way of the sterntube need not exceed the Rule keel thickness requirement.

3.13.5 For FRP sandwich hulls, the shell in way of the stern tube connection is to be either:

(a) Reduced from sandwich hull construction to single skin laminate by removal of the core and by combining the inner and outer skins. The single skin region is then to be additionally reinforced by a minimum of 50 per cent of the sum of the inner and outer sandwich laminate. The increased thickness in way of the sterntube need not be greater than the Rule keel thickness requirement.
(b) Reduced from the sandwich hull construction to a single skin laminate by removal of the core and combining the inner and outer skins. After bonding in the stern tube to the single skin laminate the foam core and the inner skin is to be reinstated.
(c) Proposals to replace the sandwich core with a core having higher core shear strength and compressive strength than that of the adjacent structure prior to bonding the tube to the inner and outer skins will be the subject of special consideration.

3.13.6 The sterntube may be connected to the shell by bonding, bolting or welding as applicable depending upon the construction material of the shell.

3.13.7 When bonding in sterntubes the bonding angle laminate weight is to be not less than the Rule minimum bottom weight. FRP tubes are to be thoroughly abraded and degreased prior to installation and laminating. Bonded in metallic tubes are to be knurled in way of the bonding material and thoroughly degreased prior to installation. During the bonding operation particular care is to be given to maintaining the sterntube alignment.

3.13.8 Where sterntubes are to be retained by bolting, they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

3.13.9 Where sterntubes are to be welded to hull insert plates full penetration welding is required.

3.13.10 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of Pt 11, Ch 2,4.16 are to be complied with.

3.13.11 The region where the shafting enters the craft, and the bearing in way, is to be adequately supported by floors or deep webs.

3.13.12 The shaft bearings are to be secured against rotation within the sterntube.

3.13.13 A suitable gland arrangement is to be provided at the inboard end of sterntubes in accordance with Pt 11, Ch 2,4.15.

3.14 Solepieces

3.14.1 The requirements for solepieces are as indicated in Table 3.3.1.

3.15 Propeller hull clearances

3.15.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in Table 3.3.2. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

Table 3.3.2 Recommended propeller hull clearances

Number of Blades	Hull clearances for single screw, in metres, *see* Fig. 3.3.8(a)				Hull clearances for twin screw, in metres, *see* Fig. 3.3.8(b)	
	a	b	c	d	e	f
3	1,20$K\delta$	1,80$K\delta$	0,12δ	0,03δ	1,20$K\delta$	1,20$K\delta$
4	1,00$K\delta$	1,50$K\delta$	0,12δ	0,03δ	1,00$K\delta$	1,20$K\delta$
5	0,85$K\delta$	1,275$K\delta$	0,12δ	0,03δ	0,85$K\delta$	0,85$K\delta$
6	0,75$K\delta$	1,125$K\delta$	0,12δ	0,03δ	0,75$K\delta$	0,75$K\delta$
Minimum value	0,10δ	0,15δ	t_R	—	3 and 4 blades, 0,20δ 5 and 6 blades, 0,16δ	0,15δ

Symbols

L_R and C_b as defined in Ch 1,6.1

$$K = \left(0,1 + \frac{L_R}{3050}\right)\left(\frac{3,48 C_b P_s}{L_R^2} + 0,3\right)$$

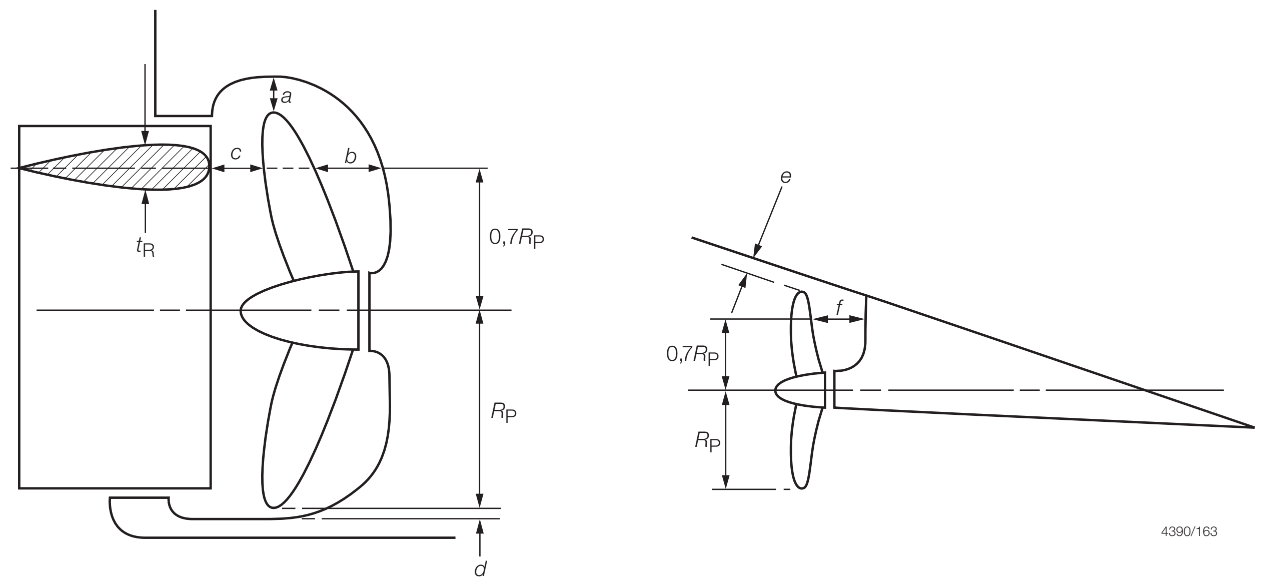
t_R = thickness of rudder, in metres measured at 0,7R_p above the shaft centreline

P_s = designed power on one shaft, in kW

R_p = propeller radius, in metres

δ = propeller diameter, in metres

NOTE
The above recommended minimum clearances also apply to semi-spade type rudders.



(a) Single screw (b) Twin screw

Fig. 3.3.8 Propeller clearance

■ *Section 4*
Fixed and steering nozzles, bow and stern thrust units

4.1 General

4.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in 4.2 to 4.4 and Table 3.4.1.

4.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see* Table 3.4.1. Nozzles exceeding this value will be specially considered.

4.2 Nozzle structure

4.2.1 For basic scantlings of the structure, *see* Table 3.4.1, in association with Fig. 3.4.1.

4.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

4.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see* Table 3.4.1.

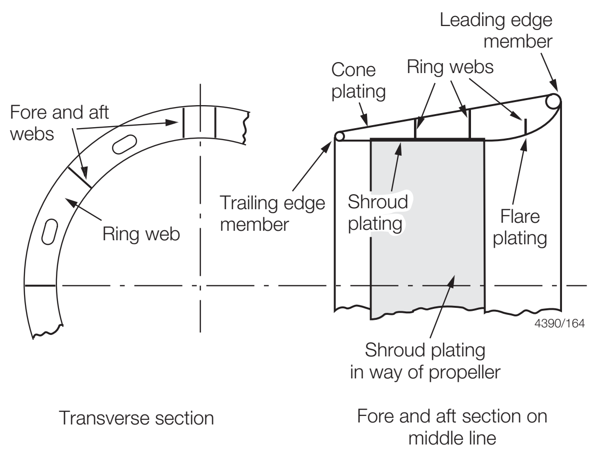


Fig. 3.4.1 Fixed and steering nozzles

4.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with Table 3.4.1, the increased thickness is to be maintained to the adjacent fore and aft web.

Table 3.4.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle Numeral	$N_N = 0{,}01 P \delta_P$
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63$ $t_s = (11 + 0{,}1 N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052 N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing $\leq 92{,}7$ N/mm^2 Torsional stress in upper stock $\leq 62{,}0$ N/mm^2
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2
Symbols	
N_N = a numeral dependent on the nozzle requirements P_s = power transmitted to the propellers, in kW δ_P = diameter of the propeller, in metres t_S = thickness of shroud plating in way of propeller tips, in mm t_p = thickness of plating, in mm t_W = thickness of webs and ring webs in way of headbox and pintle support, in mm	
NOTE Thicknesses given are for mild steel. Reductions in thickness will be considered for certain stainless steels.	

4.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

4.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

4.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see* 2.25 and 2.27, and Table 1.7.2 in Chapter 1.

4.3 Nozzle stock and solepiece

4.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in Table 3.4.1, in both the ahead and astern conditions.

4.4 Ancillary items

4.4.1 The diameter and first moment of area about the stock axis of coupling bolts and the diameter of pintles, are to be derived from 2.20 and 2.19 respectively.

4.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

4.5 Steering gear and allied systems

4.5.1 For the requirements of steering gear, *see* Pt 12, Ch 1.

4.6 Thruster unit wall thickness

4.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than:

(a) For steel hulls, the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.
(b) For aluminium hulls, the thickness of the adjacent shell plating plus 10 per cent or 1 mm whichever is the greater, subject to a minimum of 8 mm.
(c) For FRP hulls, generally the thickness of the adjacent shell laminate plus 25 per cent subject to a minimum of 8 mm. Full details of the proposed laminate and resin system are to be submitted for approval.

4.7 Thruster unit installation details

4.7.1 The method of attachment of the tube is dependent upon the tube and the craft's construction materials which may be steel, aluminium alloy or FRP.

4.7.2 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

4.7.3 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

4.7.4 For welded tube connections the welding is to be by full penetration welding.

4.7.5 For FRP tubes attached by bonding the total bonding reinforcement weight is to be at least that of the hull bottom laminate with the tube bonded internally and externally to the shell laminate. Prior to bonding *in situ* the areas to be bonded are to be thoroughly abraded and degreased and all cut FRP laminate edges resin sealed.

4.7.6 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

4.7.7 The unit is to be adequately supported and stiffened.

4.8 Novel features

4.8.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5* Stabiliser arrangements

5.1 General

5.1.1 The scantlings, arrangements and effectiveness of the stabilisers are outwith the scope of classification; however their foundations, supporting structure and watertight integrity are to be examined.

5.2 Fin stabilisers

5.2.1 Detailed plans are to be submitted clearly indicating the position, supporting structure and design loads for all fins.

5.2.2 The design, construction, operational performance and control systems of the fin stabiliser unit are outside the scope of classification.

5.2.3 Fin stabilisers are to be contained within a watertight enclosure. The purpose of the watertight enclosure is to ensure that any impact to the stabiliser will not affect the survivability or safe operation of the craft. In addition to the requirements of 5.2.4, when determining the location and extent of the watertight enclosure the following should be considered:

(a) Stabiliser blade construction material
(b) Designed failure mode of stabiliser shaft
(c) Damage stability requirements of craft
(d) Survivability of craft after impact to the stabiliser
(e) Function of space containing stabiliser.

5.2.4 For non-retractable type stabilisers, the watertight divisions forming the forward and aft boundaries of the watertight enclosure are to be arranged not less than one third of the root chord length, C, from the fore and aft extents of the stabiliser, *see* Fig. 3.5.1. Main watertight subdivision bulkheads may be considered as watertight divisions where appropriate.

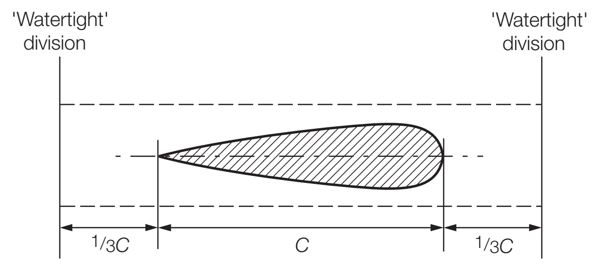


Fig. 3.5.1 Stabiliser positioning

5.2.5 For craft constructed of mild steel the watertight enclosure into which the stabilisers retract is to have a perimeter plating of the same thickness as the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the shell. For craft constructed from aluminium alloys the corrections in Ch 3,1.2.2 apply.

5.2.6 For craft constructed from composite materials the laminate thickness of the watertight enclosure into which the stabilisers retract is to be specially considered. Generally the thickness should not be less than that of the bottom shell.

5.2.7 Insert plates are to be fitted or laminate thickness increased in way of stabilisers. The thickness of the insert plate or increased laminate is to be at least 50 per cent greater than the bottom shell thickness in way, and is to extend over an area formed by 1,25 times the stabiliser root chord length and covering all operational angles. In addition, for retractable stabilisers the insert is to extend beyond the shell opening for a distance of not less than 25 per cent the length of the root chord.

5.2.8 Fin stabiliser systems are, in general, not to extend beyond the extreme moulded beam of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the forward and aft extent of the stabiliser when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

5.2.9 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where bending stresses are induced in the structure under fatigue conditions the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered on the basis of the Rules.

5.2.10 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be as specified by the designer/Builder and/or fin unit manufacturer but in no case are to be less than the scantlings for double bottoms as defined in Pt 6, Ch 3,6 for steel structures and Pt 7, Ch 3,6 for aluminium structures. Suitable access is to be provided to allow for maintenance and inspection purposes.

5.2.11 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/Builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element model, if carried out, *see* Pt 3, Ch 1,2.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from high speed impact, grounding, fouling, etc will not compromise the structural and watertight integrity of the craft.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile and shear strength values (N/mm^2).

5.2.12 Fin bearing materials and seals are to be of an approved type.

5.2.13 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and adjacent to the stabiliser installation.

5.3 Stabiliser tanks

5.3.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

5.4 Ride control systems

5.4.1 The scantlings, arrangements and effectiveness of ride control systems are currently outwith the scope of classification; however their foundations, supporting structure and watertight integrity together with the associated reaction forces on the hull structure are to be examined. Details of the loadings and supporting calculations are to be submitted with the relevant construction plans for consideration.

5.5 Motion damping arrangements and devices

5.5.1 Motion damping devices are generally outwith the scope of the Rules. Where motion damping devices are fitted the designers/Builders are to submit details of the anticipated loadings and supporting calculations for appraisal of the adjacent hull structure.

5.6 Novel features

5.6.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 6*
Particular requirements for multi-hull craft

6.1 General

6.1.1 The requirements for control systems of multi-hull craft are generally in accordance with the requirements of Sections 1 to 5 for mono-hulls.

6.2 Rudders

6.2.1 The scantlings for rudders are to be generally in accordance with Ch 3,2. Where the proposed rudder is of a novel design or the speed of the craft exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined from direct calculation methods incorporating model test results and structural analysis, as considered necessary by LR.

6.3 Sternframes and appendages

6.3.1 Sternframes and appendages are to be considered on the basis of the Rules. Reference is also to be made to Chapter 5, (Special Features) of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

6.4 Fixed and steering nozzles, bow and stern thrust units

6.4.1 In general, the requirements are to be in accordance with Ch 3,4.

6.5 Stabiliser arrangements

6.5.1 In general, the requirements for multi-hulls are to be in accordance with the requirements of Ch 3,5 and Ch 5,2.4 of Parts 6, 7 and 8, dependent upon the material of construction.

Section

■ *Section 1* General

1.1 Application

1.1.1 The contents of this Chapter are applicable to mono-hull and multi-hull craft constructed in steel, aluminium alloy or composite materials.

1.1.2 Where the requirements of Pt 1, Ch 2,1.1.11 and 1.1.14 require the craft to be subdivided for damage stability aspects these will be considered in addition to the requirements of this Part.

1.1.3 Attention is, however, to be given to any other additional statutory requirements of the National Authority in which the craft is registered.

1.2 Downflooding

1.2.1 Yachts and craft to which the *International Convention on Load Lines*, 1966 is applicable, *see* Pt 1, Ch 2,1.1.11, are to comply with the requirements of this sub-Section.

1.2.2 Doors, hatches, ventilators, windows, portlights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.2.3 Air pipes are to be fitted with automatic closing appliances unless it can be shown that, with the craft at its summer load waterline, the openings will not be immersed at an angle of heel of 40°, or the angle of downflooding if this is less than 40°.

1.3 Definitions and symbols

1.3.1 The **down flooding angle** is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.3.2 L_L is the loadline length as defined in Ch 1,6.2.3.

1.3.3 Position 1 and Position 2 are as defined in Ch 1,6.10.

1.4 Bolted connections

1.4.1 Bolted connections are generally to be in accordance with Table 4.1.1. Further requirements are contained throughout this Chapter.

Table 4.1.1 Bolt pitch requirements for structural connections

Location	Pitch
Manhole covers to fuel tanks	$6d_b$
Manhole covers to water tanks	$8d_b$
Covers over void tanks/cofferdams	$10d_b$
Unstiffened portable plates in decks	$5d_b$
Bolted watertight door frames	$8d_b$
Window frames to superstructure	$20d_b$

NOTE
d_b is the diameter of the bolt.

Section 2
Bulkhead openings

2.1 General

2.1.1 In addition to the requirements of this Section, where compliance with Pt 4, Ch 2,9 and Chapter X of SOLAS 1974, as amended *(High Speed Craft Code)*, is required, the number and construction of the watertight doors in bulkheads will be considered in accordance with these requirements. Each watertight door is to be subjected to a pressure test, *see* Table 1.7.1 in Chapter 1. The test may be carried out either before or after the door is fitted. Regulations regarding openings in watertight bulkheads relevant to passenger or cargo craft, as appropriate, contained in the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments, and Pt 4, Ch 2,9 are also to be complied with.

2.2 Openings in bulkheads below the freeboard deck

2.2.1 Certain openings below the freeboard deck are permitted, but these must be kept to a minimum and provided with means of closing to watertight standards. All such openings are to be to the satisfaction of the Surveyor.

2.3 Watertight doors

2.3.1 Watertight doors are to be efficiently constructed and fitted, and are to be capable of being operated when the craft is listed up to 15° either way. They are to be operated under working conditions and hose tested in place. *See* Ch 1,7.3.

2.3.2 Where the doors are fitted in watertight bulkheads they are to be of equivalent strength to the unpierced bulkhead and capable of being closed watertight. Watertight doors are to be of a type, approved and pressure tested, *see* Table 1.7.1 in Chapter 1, from both sides for the maximum head of water indicated by any required damage stability calculations or up to the bulkhead deck whichever is the greater.

2.3.3 Indicators are to be provided on the bridge showing whether the doors are open or closed.

2.3.4 Doors are to be capable of being operated from both sides of the bulkhead. Power operated sliding doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms.

2.3.5 Doors not required to be used at sea may be of the hinged or sliding type. A notice is to be fixed on the closing appliance saying it should be kept closed at all times while the craft is at sea.

2.3.6 Watertight doors which are intended to be used while at sea are to be of the sliding type capable of being remotely closed from the bridge. An audible alarm is to be provided at the door closure. The power, control and indicators are to be operable in the event of main power failure. Particular care is to be paid to minimising the effect of control system failure.

2.3.7 As an alternative to the sliding doors required by 2.3.6, special consideration will be given to the fitting of hinged watertight doors where it can be shown that they are as effective as the sliding type. A suitable log-book system is to be operated to ensure that such doors remain closed except when in use for access.

2.3.8 Subject to the requirements of 2.3.6 and 2.3.7, hinged watertight doors of approved pattern may be fitted in 'tween decks in approved positions. The hinges of these doors are to be fitted with a pin or bush of a suitable copper alloy in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or of an equivalent material acceptable to Lloyd's Register (hereinafter referred to as 'LR').

2.3.9 No accesses are to be fitted in collision bulkheads. In particular designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted subject to special consideration. Where accesses are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible. The closing appliances are to be watertight, open into the fore peak compartment and consideration will be given to operation from one side only.

2.4 Pipe and cable ducts, ventilation trunks and other penetrations

2.4.1 Where subdivision and damage stability requirements apply and where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

2.4.2 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding pressures to which they may be subjected, and are to be made watertight.

Section 3
Double bottom openings

3.1 General

3.1.1 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.1.2 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

3.2 Requirements

3.2.1 A plan showing the location of manholes and access openings within the double bottom is to be submitted. Attention is to be given to any relevant Statutory Requirements of the National Authority of the country in which the craft is to be registered.

3.2.2 The number and positioning of manholes are to be such that access under service conditions is neither difficult nor dangerous. Attention is to be given to any relevant international regulations regarding the minimum size of access openings.

3.2.3 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.2.4 The size of opening is not, in general, to exceed 50 per cent of the double bottom depth, unless edge reinforcement is provided. In way of outboard ends of floors and fore and aft girders at transverse bulkheads, the number and size of holes are to be kept to a minimum, and the openings are to be circular or elliptical. Edge stiffening may be required in these positions.

3.2.5 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or double plate bulkheads within one-third of their length from either end, nor in floors or double bottom girders close to their span ends, below the heels of pillars, nor in way of mast steps, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

3.2.6 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.2.7 Air and drain holes, notches and scallops are to be in accordance with Ch 2,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

3.3 Alternative arrangements

3.3.1 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

■ *Section 4*
Side and stern doors and other shell openings

4.1 General

4.1.1 These requirements cover cargo and service doors in the craft side (abaft the collision bulkhead) and stern area, below the freeboard deck and in enclosed superstructures.

4.1.2 For the requirements of bow doors, *see* Ch 5,4 of Parts 6 and 7 for steel and aluminium alloy construction respectively.

4.1.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure. *See also* Ch 1,6.8.2 and 6.9.2.

4.1.4 In general, and for passenger craft in particular, the lower edge of door openings are not to be below a line drawn parallel to the freeboard deck at side, which is at its lowest point at least 230 mm above the upper edge of the uppermost Load Line.

4.1.5 When the lower edge is below the uppermost Load Line, the arrangement will be specially considered. Special consideration is to be given to preventing the spread of leakage water over the deck. The reference to the uppermost Load Line is to be taken as the tropical fresh water line.

4.1.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two 'tween decks above the waterline.

4.1.7 For passenger craft the following is also applicable:

(a) Gangway, cargo and service ports fitted below the margin line, *see* 1.2.2, are to satisfy the strength requirements given for side doors in this Section. They are to be effectively closed and secured watertight before the craft leaves port, and are to be kept closed during navigation. Such ports are not to have their lowest point below the deepest subdivision Load Line.
(b) Where the inboard end of a rubbish chute is below the margin line in a passenger craft, the inboard end cover is to be watertight and, in addition to the discharge flap interlock, a screwdown automatic non-return valve is to be fitted in an easily accessible position above the deepest subdivision. The valve is to be controlled from a position above the bulkhead deck and provided with an open/shut indicator, and kept closed when not in use. A suitable notice is to be displayed at the valve position.

4.1.8 Where doors and platforms are fitted in the shell, the structural and watertight integrity of the hull is to be maintained. Such doors and platforms are not to lead directly into the craft and an internal watertight compartment is to be provided in way of the shell openings. The doors and platforms are to be arranged to open outwards. The sill height of the access hull opening is not to be less than 300 mm above the waterline and the sill height of the internal access is to be not less than 300 mm higher than the hull sill. Alternative arrangements will be considered.

4.1.9 Doors may be of steel, aluminium alloy or FRP construction and are to be efficiently connected to the adjoining structure and of equivalent strength and are to have adequate securing and sealing arrangements. It is recommended that doors are hinged about their forward edges and open outwards. Details are to be submitted for approval. Other materials will be specially considered.

4.1.10 For craft complying with the requirements of this Section, the securing, supporting and locking devices are defined as follows:

(a) A securing device is used to keep the door closed by preventing it from rotating about its hinges or other pivoted attachments to the craft.

(b) A supporting device is used to transmit external and internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

(c) A locking device locks a securing device in the closed position.

4.2 Symbols

4.2.1 The symbols used in this Section are defined as follows:

σ = bending stress, in N/mm^2

σ_e = equivalent stress, in N/mm^2

$= \sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2

σ_o is defined in Ch 3,1.2.

4.3 Scantlings

4.3.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.3.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below. *See* Ch 3,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.3.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the craft structure.

4.3.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.3.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of 4.3.4. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with 4.3.4.

4.3.6 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between shell frames and door stiffeners.

4.3.7 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.3.8 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.3.9 The buckling strength of primary members is to be specially considered.

4.3.10 All load transmitting elements in the design load path from door through securing and supporting devices into the craft structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices.

4.4 Doors serving as ramps

4.4.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks. *See* Ch 5,3 of Parts 6, 7 and 8 for steel, aluminium alloy and composite construction respectively.

4.4.2 The design of the hinges for these doors is to take into account the craft angle of trim or heel which may result in uneven loading of the hinges.

4.5 Closing, securing and supporting of doors

4.5.1 Doors are to be fitted with adequate means of closing, securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is not generally to exceed 3 mm.

4.5.2 Securing devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.5.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.5.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 (0,153 tonne-f/m^2) acting on the maximum projected area in the open position.

4.5.5 The spacing for cleats or closing devices is not to exceed 2,5 m and cleats or closing devices are to be positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.5.6 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the freeboard deck with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the freeboard deck. This remote control is provided for the:

(a) Closing and opening of the doors.
(b) Associated securing and locking devices.

4.5.7 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.5.8 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately prior to the craft leaving the berth and that this operation is to be entered in the craft's log. This notice is to be supplemented by warning indicator lights indicating if any door is not fully closed, secured and locked.

4.5.9 Means are to be provided to prevent unauthorised operation of the doors.

4.5.10 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.5.11 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:
External force:
$F_e = Ap_e + F_p$ kN
Internal force:
$P_i = P_o + 10W$ kN
(b) Design forces for securing or supporting devices of doors opening outwards:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W + F_p$ kN
(c) Design forces for primary members:
External force:
$F_e = Ap_e$ kN
Internal force:
$P_i = P_o + 10W$ kN

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, not to be taken less than 25 kN/m^2
A = total area of door opening, in m^2, to be determined on the basis of the load area taking account of the direction of pressure
F_p = total packing force, kN. When packing is fitted, the packing force per unit length is to be specified, normally not to be taken less than: 5 kN/m
P_c = accidental force, in kN, due to loose cargo, etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose cargoes
P_o = the greater of P_c and $5A$ kN
W = weight of the door, in tonnes.

4.6 Systems for indication and monitoring

4.6.1 The following requirements apply to doors in the boundaries of special category spaces or ro-ro spaces, as defined in the SOLAS Convention, through which such spaces may be flooded. For cargo craft, where no part of the door is below the uppermost waterline and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.6.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.6.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.6.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.6.5 For passenger craft, a water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of any leakage through the doors. For cargo craft, a water leakage detection system with audible alarm is to be arranged to provide an indication to the navigation bridge.

Table 4.4.1 Permissible stress for bolts, closing and supporting devices

Material	Closing and supporting devices			Thread of bolts
	Direct stress N/mm^2	Shear stress N/mm^2	Equivalent stress N/mm^2	Direct stress N/mm^2
Steel	$\dfrac{120}{k_s}$	$\dfrac{80}{k_s}$	$\dfrac{150}{k_s}$	$\dfrac{120}{k_s}$
Aluminium	$\dfrac{64}{k_a}$	$\dfrac{43}{k_a}$	$\dfrac{80}{k_a}$	$\dfrac{64}{k_a}$

NOTES

1. $k_s = \dfrac{235}{\sigma_o}$, σ_o as defined in Ch 3,1.2.1

2. $k_a = \dfrac{120}{\sigma_{ya}}$, σ_{ya} as defined in Ch 3,1.2.2

4.7 Design of securing and supporting devices

4.7.1 Securing devices and supporting devices are to be designed to withstand the forces given in 4.5.11 using the permissible stresses given in Table 4.4.1. The terms 'securing device' and 'supporting device' are defined in Pt 6, Ch 5,4.3.

4.7.2 The nominal tensile stress in way of threads of bolts is not to exceed the permissible stress given in Table 4.4.1. The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces.

4.7.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed $0{,}8\sigma_o$. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.7.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.7.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.7.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with 4.5.3 and taking account of the available space in the hull for adequate support.

4.7.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses referred to in 4.7.1.

4.8 Operating and Maintenance Manual

4.8.1 An Operating and Maintenance Manual for the doors is to be provided on board and is to contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions (e.g. service area restrictions, acceptable clearances for supports);
(c) maintenance and function testing;
(d) register of inspections and repairs.

This Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the craft's staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.8.2 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

4.9 Engine removal arrangements

4.9.1 Where portable plates are required for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced structure and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

4.10 Testing on completion

4.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

Section 5
Hatches on exposed decks

5.1 General

5.1.1 This Section applies to small hatchways or access openings in the positions indicated in Fig. 4.5.1.

5.1.2 The number and size of hatchways and other access openings are to be kept to the minimum consistent with the satisfactory operation of the craft.

5.1.3 Hatch covers are to be weathertight when closed, of substantial construction and generally hinged. The means of securing are to be such that weathertightness can be maintained in any sea condition. Details are to be submitted for approval.

5.1.4 Hatch covers may be of steel, aluminium alloy or FRP construction. Where toggles are fitted, their diameter and spacing are to be in accordance with an ISO Standard or equivalent.

5.1.5 Hatches on the weatherdeck in the forward 0,25L_R or to machinery spaces are to be hinged on the forward side.

5.2 Coaming heights

5.2.1 Hatch coamings are to have a height above the deck surface in accordance with Table 4.5.1. Lower heights may be considered in relation to operational requirements and the nature of the spaces to which access is given.

5.2.2 Flush hatches will be specially considered.

5.2.3 Rope hatches may be accepted with reduced coamings, but generally not less than 380 mm, provided they are well secured and opened only at the Master's discretion. A suitable notice is to be displayed at the hatch.

5.3 Scantlings

5.3.1 Hatch covers are to be of equivalent strength to the deck on which they are fitted.

Table 4.5.1 Height of hatch coamings

Location/Access	Height (mm) (*see* Note 2)
(a) Weather deck/machinery compartment	460
(b) Weather deck/lower deck accommodation	230
(c) Weather deck/cargo hold	460

NOTES
1. For locations (a) and (b), *see* Fig. 4.5.1.
2. Reduced coaming heights will be specially considered based on a craft's service area restriction notation.

5.3.2 The thickness of the coamings is to be not less than the Rule thickness for the deck in the positions in which they are fitted. Stiffening of the coaming is to be appropriate to its length and height.

5.3.3 The covers are to be adequately stiffened.

5.4 Closing devices

5.4.1 Hinges are not to be used as securing devices unless specially considered.

5.4.2 Escape hatches are to be capable of being opened from either side.

5.5 Engine removal hatches

5.5.1 Where portable plates are required in decks for unshipping machinery or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck and are secured by gaskets and closely spaced bolts. The pitch spacing of the bolts will be specially considered depending on the hatch stiffening and support arrangements but should not exceed ten diameters.

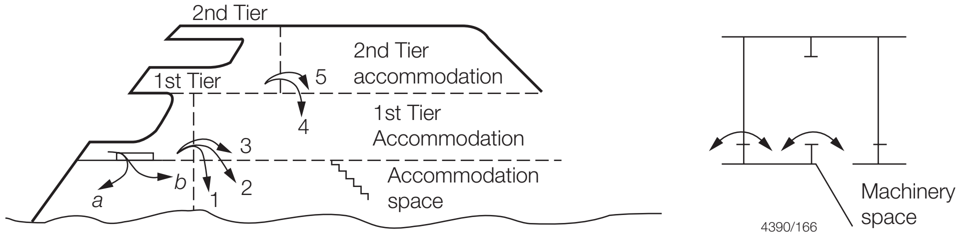


Fig. 4.5.1 Arrangement of doors, sills and hatch coamings

5.6 Structural details

5.6.1 Various structural details for hatchways and access openings are given in the LR *Guidance Notes for Structural Details.*

5.7 Effective support for large hatch covers

5.7.1 The weight of hatch covers and any loads carried thereon, together with inertial forces generated by craft motions, are to be effectively transmitted to the craft structure. This may be achieved by continuous structural contact of the hatch cover with the craft structure or by means of defined bearing pads. The bearing pressure will be specially considered depending on the construction material.

5.8 National Authority requirements

5.8.1 The height of the hatch coaming may be subject to additional requirements of the National Authority.

5.9 Exceptions

5.9.1 Subject to the agreement of LR exceptions may be given to the requirements of this Section where they interfere with the operation of the craft. Such exceptions will be specially considered.

5.10 Testing upon completion

5.10.1 The items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

5.11 Standard designs

5.11.1 Standard designs of hatches may be accepted, provided they are designed and manufactured in accordance with the requirements of a recognised National or International Standard which gives reasonable equivalence to the requirements of this Section.

5.11.2 Standard proprietary flush hatches, not exceeding 650 mm x 650 mm clear opening, which are of a type holding a valid Type Approval by LR, may be accepted for under deck access in non-working areas of craft below 24 m in length, L_R, dependent upon the Service Group Notation. Where the hatch type is not type approved, full details, including the material specification, are to be submitted for approval in each case.

5.12 Novel features

5.12.1 Hatchways of novel or unusual design will be specially considered.

Section 6 Miscellaneous openings

6.1 General

6.1.1 This Section gives requirements for external doors, manholes and flush scuttles, hatchways within enclosed superstructures or ’tween decks and companionways, doors and accesses on weather decks.

6.1.2 Those items listed in Table 1.7.1 in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

6.2 External doors

6.2.1 Door sills are to have a height above the deck surface in accordance with Table 4.6.1.

Table 4.6.1 Height of door sills

Position/access	Height (mm)
(1) Weather deck/machinery compartment, *see* Note 2	460
(2) Weather deck/lower accommodation	230
(3) Weather deck/1st tier accommodation	150
(4) 1st tier/1st tier accommodation	100
(5) 1st tier/2nd tier accommodation	50

NOTES
1. For positions (1), (2), etc., *see* Fig. 4.5.1
2. Where the access to the machinery space is protected by an outer weathertight door, the inner door sill or hatch coaming may be 230 mm high in association with an outer sill height of 230 mm.

6.2.2 Reduced sill heights for doors will be considered as follows:
(a) dependent upon the service group notation,
(b) for doors which will only be used when the craft is in harbour, or calm water,
(c) where the sill height interferes with the operation of the craft,
(d) where doors do not give access to spaces below the freeboard deck.

6.2.3 The height of the door sill may be subject to additional requirements of the National Authorities.

6.2.4 Where the sill heights do not comply with the requirements of Table 4.6.1, interior deck openings are to be treated as if they were exposed on the weather deck.

6.3 Manholes and flush scuttles

6.3.1 Manholes and flush scuttles fitted in Positions 1 and 2, or within superstructures other than enclosed superstructures, are to be closed by substantial covers capable of being made watertight. Unless secured by closely spaced bolts, the covers are to be permanently attached.

6.4 Hatchways within enclosed superstructures or ’tween decks

6.4.1 The requirements of Section 5 are to be complied with where applicable.

6.4.2 Access hatches within a superstructure or deckhouse in Position 1 or 2 need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

6.5 Companionways, doors and accesses on weather decks

6.5.1 Companionways on exposed decks are to be of equivalent construction, weathertightness and strength to a deckhouse in the same position and effectively secured to the deck.

6.5.2 Access openings in:

(a) Bulkheads at ends of enclosed superstructures,

(b) Deckhouses or companionways protecting openings leading into enclosed superstructures or to spaces below the freeboard deck, and

(c) Deckhouses on a deckhouse protecting an opening leading to a space below the freeboard deck,

may be fitted with doors of steel, aluminium alloy, FRP or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by 6.2. Double doors are to be equivalent in strength to the unpierced bulkhead, and in Position 1, a centre pillar is to be provided which may be portable.

6.5.3 Elsewhere doors may be of hardwood or equivalent material and are to be of equivalent strength to the unpierced bulkhead.

6.5.4 Portlights or windows in doors are to comply with the requirements given in Section 7. Deadlights or storm covers may be external.

6.5.5 When the closing appliances of openings in superstructures and deckhouses do not comply with 6.5.2, interior deck openings are to be treated as if exposed on the weather deck.

6.5.6 Doors on the weather deck (first tier) protecting direct access to machinery spaces are to be of substantial construction in accordance with approved plans or a recognised National or International Standard. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a sill height in accordance with 6.2.

6.5.7 Doors on the weather deck to accommodation or spaces protecting access below are to be as required by 6.5.6 with a minimum of four clips.

6.5.8 Where wood doors are proposed on the weather deck in lieu of doors as per 6.5.7, they are to be strongly constructed of hardwood not less than 45 mm thick and double gasketed. For doors in exposed locations, additional securing arrangements by slip bolts, clamps or equivalent will be required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional security arrangements are to be operable from both sides.

6.5.9 FRP doors are not to be fitted in access openings where ‘A’, ‘B’ or ‘C’ class fire integrity is required, or in engine room casings.

6.5.10 Doors in the second tier are to be as required by 6.5.6 with a minimum of four clips.

■ *Section 7*
Portlights, windows and viewing ports, skylights and glass walls

7.1 General

7.1.1 This Section gives the requirements for portlights, windows, viewing ports, sliding glass doors, glass walls, skylights, glazing materials, deadlights and storm covers.

7.1.2 Side scuttles and portholes are considered to be portlights.

7.1.3 A plan showing the location of portlights, windows, viewing ports, skylights and glass walls is to be submitted.

7.1.4 Portlights and windows, together with their glazing and deadlights if required, are to be of an approved design or in accordance with a recognised National or International Standard.

7.1.5 Glass in portlights, windows and skylights is to be thermally toughened safety glass with a thickness in accordance with approved plans or a recognised National or International Standard relative to their location.

7.1.6 Where consideration is given to the use of glazing materials other than thermally toughened glass, the thickness and arrangements are to take account of any different material properties and be approved.

7.1.7 The acceptance of ‘glued-in’ glazing material, when proposed, will be subject to Type Approval or individual approval and tests as appropriate.

7.1.8 The use of rubber frames is not generally acceptable.

7.1.9 In position 2, cabin bulkheads and doors are considered effective between portlights or windows and access below.

7.1.10 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2. Round or oval openings having areas exceeding 0,16 m^2 shall be treated as windows.

7.1.11 Windows are defined as being rectangular openings generally, having a radius at each corner relative to the window size and round or oval openings with an area exceeding 0,16 m^2.

7.2 Applications

7.2.1 As indicated in 1.1. *See also* Part 4 for additional requirements for yachts.

7.3 National Authority requirements

7.3.1 In addition to the requirements of this Section, where relevant, care is to be given to the statutory requirements of the National Authority.

7.4 Portlights

7.4.1 Portlights are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate. Where the portlight is not type approved, full details are to be sumitted for approval in each case.

7.4.2 Portlights may be round, elliptical or elongated and are to be of substantial construction

7.4.3 Portlights are not to be fitted in machinery spaces.

7.4.4 No portlight is to be fitted in such a position that its still is below a line drawn parallel to the freeboard deck at side and having its lowest point 2,5 per cent of the breadth, *B,* above the load waterline corresponding to the summer freeboard (as defined in Ch 1,6.2.7), or 500 mm, whichever is the greater distance, *see* Fig. 4.7.1.

7.4.5 Deadlights or storm covers for portlights are to be provided in accordance with 7.12.

7.5 Windows

7.5.1 Windows are to be in accordance with a recognised National or International Standard or of a type accepted for the respective position and having a valid LR Type Approval certificate.

7.5.2 Where the window is not type approved, full details are to be submitted for approval in each case and the prototype tested in accordance with the requirements of 7.5.3 to 7.5.5.

7.5.3 A hydrostatic test is to be carried out in order to examine watertightness. A design pressure p, where p is given in 7.8.1, is to be applied to the external face of the window and maintained for at least 15 minutes.

7.5.4 A hydrostatic test is to be carried out in order to examine the capability of the frame, and glass retaining arrangements. A design pressure 4p, where p is given in 7.8.1, is to be applied to the external face of the window. Alternatively, this test may be carried out using a steel plate in place of the glass. Ideally the steel plate should be of a suitable reduced thickness to simulate the flexural performance of the glass.

7.5.5 Equivalent proposals for testing will be considered. Where alternative testing procedures are proposed, these are to be agreed with LR before commencement.

7.5.6 Window glazing is, in general, to be toughened safety glass, fitted in substantial frames supporting both faces of the glass and effectively secured to the structure. Metal to glass contact is to be avoided.

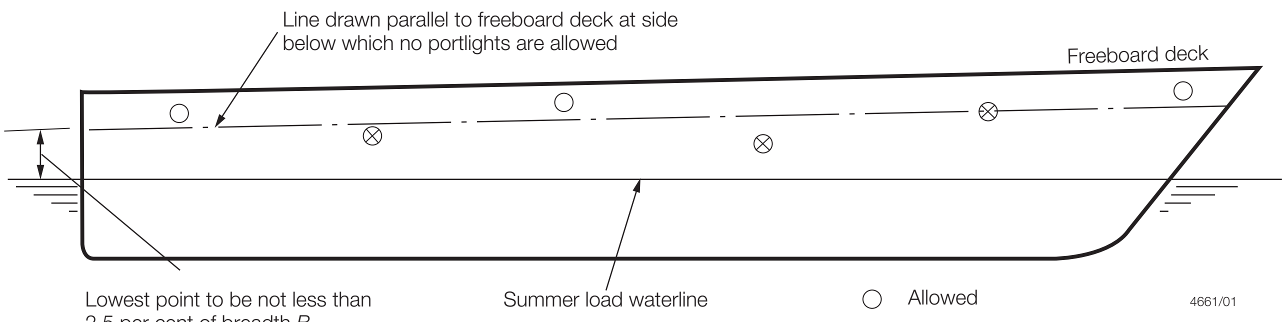


Fig. 4.7.1 Position of portlights

7.5.7 In general, no windows are to be fitted in the following locations:
(a) below the freeboard deck;
(b) in the first tier end bulkheads or sides of enclosed superstructures; or
(c) in first tier deckhouses that are considered buoyant in the stability calculations.

7.5.8 Wheelhouse window glazing is to be toughened safety glass, or where it is of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

7.5.9 Large windows in the aft end of superstructure or deckhouses will be specially considered.

7.5.10 Openings in the shell for windows are to have well rounded corners.

7.5.11 Storm covers or deadlights for windows are to be provided in accordance with 7.12.

7.6 Viewing ports

7.6.1 In general, viewing ports are not to be fitted in the bottom shell of high speed craft.

7.6.2 Viewing ports are to be watertight and of substantial construction in accordance with approved plans.

7.6.3 Glazing is to be fitted in substantial frames supporting both faces of the glazing and effectively secured to the hull structure.

7.6.4 Where practicable, viewing ports are to be fitted with efficient, hinged, deadlights which are capable of being effectively closed and secured watertight, with or without the glazing in place.

7.6.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight. Where a deadlight is fitted, this test is also to be carried out with the glazing removed and the deadlight closed.

7.7 Sliding glass doors or 'glass walls'

7.7.1 Large glass doors or windows in the aft end of superstructures and deckhouses and other large glass structures forming the sides, ends or roofs of deckhouses will be specially considered.

7.7.2 When sliding glass doors are provided, or a 'glass wall' which includes an access, an alternative access or exit from the space is to be provided and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Sill heights are, in general, to be in accordance with 6.2.

7.7.3 The glazing is to be toughened safety glass, or equivalent, and of substantial thickness in accordance with 7.8, 7.9 or 7.10 as appropriate.

7.7.4 Storm covers or roller shutters are to be provided in accordance with 7.12.11.

7.8 Toughened safety glass thickness

7.8.1 The thickness, t, of toughened safety glass is to be not less than 6 mm or that given by the following expression, whichever is the greater:
for glazing of rectangular form

$$t = 0{,}005b\sqrt{\beta\, p} \text{ mm}$$

for glazing of circular form

$$t = 0{,}00559r\sqrt{p} \text{ mm}$$

where
a = length of longer side of window, in mm
b = length of shorter side of glazing, in mm
p = design pressure in kN/m^2, as defined in Pt 5, Ch 3,3.1 and Ch 4,3.1
r = radius of the glazing, in mm
A_R = aspect ratio of window
= a/b
β = $-0{,}17 + 0{,}54A_R - 0{,}078A_R^2$ for $A_R \leq 3$
= 0,75 for $A_R > 3$.

7.8.2 For windows of trapezoidal form, the length of window, a, is to be taken as the mean of the length of the longer sides. The value of b, the length of the shorter side, may be similarly determined.

7.9 Laminated glass thickness

7.9.1 Laminated toughened safety glass may be used having a thickness greater than the single plate toughened safety glass for the same size window, as given by:

$$t_s^2 = t_{i1}^2 + t_{i2}^2 + \ldots\ldots + t_{in}^2 \text{ mm}$$

where
n = number of laminates
t_i = thickness of laminate, in mm
t_s = thickness of equivalent single plate, in mm.

Alternative arrangements that do not meet the above thickness requirement will be specially considered, provided that equivalent strength and bending stiffness to that of a single, thermally toughened pane of thickness, t_s, can be demonstrated in a four-point bending test in accordance with EN-ISO 1288-3 or an equivalent recognised National or International Standard, using no fewer than ten samples. The lower limit of the 90 per cent confidence level interval for the laminated pane shall not be less than the same for monolithic toughened safety glass. Small scale punch test or ring-in-ring test methods shall not be used.

7.10 Other glazing materials

7.10.1 Materials other than glass may be used for windows, except for those in the wheelhouse, with the thickness obtained by multiplying the thickness for toughened safety glass by a factor of 1,3 for polycarbonate and 1,5 for acrylic. Consideration will be given to composite and multi-layer constructions where documented results of a pressure test confirm that the proposed construction, when fitted in its appropriate frame, is able to withstand a test pressure of four times the design pressure and remain watertight.

7.11 Openings and framing requirements

7.11.1 The strength and dimensions of the frame section are to be appropriate to the size of the window, the type of glazing being used and its method of bedding. The glazing is to be secured to its frame in accordance with the Manufacturer's instructions and recommendations; metal to glass contact is to be avoided.

7.11.2 Rubber frames are not acceptable for windows in Positions 1 and 2, and are not generally acceptable in any other position in external casings. Any proposals to fit rubber frames are to be submitted for consideration. The proposed locations, frame dimensions, glass thicknesses and the results of any tests carried out, are to be forwarded.

7.12 Deadlights and storm covers

7.12.1 Portlights fitted to spaces below the weather deck, or to spaces within enclosed superstructures, are to be fitted with efficient, hinged, inside deadlights which are capable of being effectively closed and secured watertight below the weather deck and weathertight above the weather deck.

7.12.2 In service craft less than 24 m Rule length, L_R, and yachts, portlights in the hull in way of accommodation may have portable deadlights, provided that they are stored adjacent to the portlight and can be readily fitted. Also, in the case of these craft, portlights in superstructures or deckhouses do not require to have deadlights, unless on the weather deck in exposed positions or protecting direct access below, in which case, they are to be provided with deadlights or storm covers.

7.12.3 For craft in **Service Group G1**, storm covers or deadlights are generally not required for windows or portlights in superstructures or deckhouses.

7.12.4 For craft in **Service Group G2**, storm covers or deadlights are required for:

(a) 50 per cent of the windows and portlights in the front of the superstructure or deckhouse on the weather deck.
(b) The windows and portlights in the forward half of the superstructure or deckhouse side on the weather deck, except where these are interchangeable port and starboard, in which case a sufficient number to fit the forward half of one side is to be provided.
(c) Each different size of window and portlight.

7.12.5 For craft in **Service Groups G2A and G3**, storm covers or deadlights are required for:

(a) All windows and portlights in the front of the superstructure or deckhouse on the weather deck.
(b) All windows and portlights in the sides of the superstructure or deckhouse on the weather deck, except where they are interchangeable port and starboard, in which case a sufficient number to fit any one side are to be provided.
(c) Each different size of window and portlight.

7.12.6 For craft in **Service Groups G4** and **G5**, storm covers or deadlights are required as follows:

(a) If fitted in a deckhouse in Position 1, windows are to be provided with strong, hinged, weathertight storm covers. However, if there is an opening leading below deck in this deckhouse, this opening is to be treated as being on an exposed deck and is to have weathertight protection.
(b) Portlights and windows at the shell in Position 2, protecting direct access below, are to be provided with strong permanently attached deadlights.
(c) Portlights and windows at the shell in Position 2, not protecting direct access below, are to be provided with strong portable steel covers for 50 per cent of each size, with means for securing at each window.
(d) Portlights and windows set inboard from the shell in Position 2, protecting direct access below, are either to be provided with strong permanently attached dead-lights or, where they are accessible, strong permanently attached external storm covers instead or internal dead-lights.
(e) Portlights and windows set inboard from the shell in Position 2, not protecting direct access below, do not require deadlights or storm covers.
(f) Windows in the shell above Position 2 are to be provided with strong portable internal storm covers for 25 per cent of each window, with means of securing being provided at each window.
(g) Where windows are permitted in an exposed bulkhead on the weather deck in the forward $0{,}25L_L$, strong external storm covers are to be provided, which may be portable and stored adjacent.

7.12.7 Deadlights and storm covers are not required for second tier portlights or windows in deckhouses without direct access below.

7.12.8 Where the wheelhouse is in Position 2, in lieu of storm covers being provided for the wheelhouse windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the wheelhouse, may be accepted. If this arrangement is accepted, adequate means of draining the wheelhouse are to be provided.

7.12.9 If necessary, for practical considerations, the storm covers may be in two parts.

7.12.10 Deckhouses situated on a raised quarter deck may be treated as being in Position 2 as far as the provision of deadlights is concerned, provided the height of the raised quarter deck is equal to, or greater than the standard height.

7.12.11 Sliding glass doors are to be provided with storm covers of strong construction, or, in the case of a 'glass wall', this may be protected by a strongly constructed roller shutter or equivalent, which can be readily lowered and secured to provide adequate protection. When necessary, additional portable supports are to be provided for the cover. The arrangements are to be in accordance with approved plans. Alternative arrangements will be specially considered. In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over.

7.12.12 Deadlights and storm covers are to be weathertight and of equivalent strength to the surrounding structure.

7.12.13 Portable deadlights and storm covers are to be clearly marked to indicate which portlights or windows they fit and stowed in such a way as to be readily fitted.

7.13 Emergency exits

7.13.1 Portlights or windows intended as emergency escapes are to be capable of being opened from both sides and have a minimum clear opening of 600 mm x 600 mm.

7.14 Skylights

7.14.1 Skylights, where fitted, are to be of substantial construction and securely attached to their coamings. The height of the lower edge of opening is to be as required by 5.2.1. The scantlings of the coaming are to be as required by 5.3.2. The thickness of glasses in fixed or opening skylights is to be appropriate to their size and position as required for portlights or windows. Glasses in any position are to be protected from mechanical damage, and where fitted in Positions 1 or 2 (as defined in Ch 1,6.10) are to be provided with robust deadlights or storm covers permanently attached.

7.15 Testing on completion and installation

7.15.1 In order to demonstrate that the requirements of this Section are met the closing arrangements are to be operated under working conditions to the satisfaction of the Surveyor.

7.15.2 The items listed in Table 1.7.1, in Chapter 1, are to be hose tested to the satisfaction of the Surveyor.

7.16 Bonded windows and side scuttles

7.16.1 A 'bonded window or bonded side scuttle' is one in which the glazing material is secured in its frame from the outside of the ship by glue or other adhesive material. No mechanical fixing is provided for the glazing. Bonded windows and bonded side scuttles are to comply with the requirements of 7.5 and 7.4 respectively, in addition to the requirements in this Section. Proposals to secure glazing from the inside of the ship are to be specially considered using the requirements in this Section as a basis. It should be noted that bonding from the inside is not recommended and where it is proposed, further testing will be required. Non-load-bearing secondary bonded glazing, e.g., glazing to improve thermal insulation, is not required to comply with the requirements of this sub-Section.

7.16.2 The adhesive is to be flexible enough to support the glazing without holding it firm. The glue strip is to be elastic, with width and thickness designed to allow the glazing to move in both directions in the plane of the glazing without undue forces on the bonding or the substrate. The glass is to be free to settle under load and not be forced to follow deflections in the supporting structure. If substantial racking of the glazing opening under load is expected, the bonding is to be designed to accommodate such deflections.

7.16.3 Bonded windows and side scuttles may be considered as acceptable, in general, on yachts, depending on their position, size of yacht and applicable statutory requirements, noting the distinction between glazing and the frame, which may have different requirements.

7.16.4 Bonded windows and side scuttles are not permitted in galley areas, including glazing in galley doors (internal or external). They are not permitted on escape routes and evacuation routes where a fire rating is required. The fire integrity of bulkheads is not to be impaired.

7.16.5 The failure of laminated glass is considered to pose a lower risk to safety than that of single pane glass. In the event of breaking, laminated glass more readily holds together and tends not to break up into large sharp pieces. Therefore, in general, laminated glazing is preferred. When laminated glass is used, the sealant is to be compatible with the interlayer. Lamination thickness is to be in accordance with 7.9.1. Special consideration will be given to single pane toughened safety glass.

7.16.6 The durability of the adhesive and the sealant in the long-term marine environment is to be considered in the approval process. Adhesive is to be approved in accordance with Vol 2, Pt 2, Ch 14,2.15. The adhesive bead is to be resistant to or protected from UV radiation, either by an optically dense area at the edges of the glazing or by overlapping trim or UV shielding tape. The adhesive bead is to be resistant to or protected from fungal attack. Arrangements are to be in accordance with the adhesive manufacturer's published guidelines and relevant LR Rules.

7.16.7 The edges of the bonding recess are to be rounded to facilitate the application of the sealant without air entrapment. The width of the gap between the flange and the glazing is to be large enough to accommodate the movement of the glazing as a result of hull deflection and thermal expansion, *see* Fig. 4.7.2. Recommended gap widths for bonded windows are to be taken as:

Gap width	Length of longest side of window
10–15 mm	< 1,5 m
15–20 mm	1,5–3,0 m

7.16.8 The minimum adhesive width and thickness are to be in accordance with the adhesive manufacturer's published guidelines.

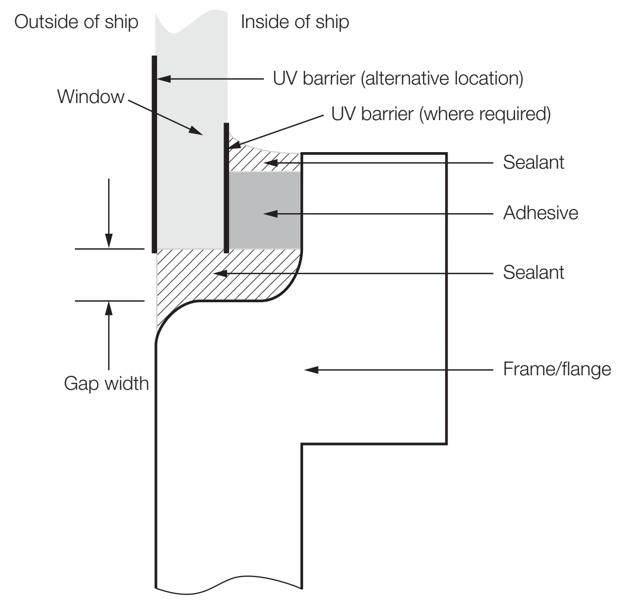


Fig. 4.7.2
Gap width between flange and window, bonded from the outside of the ship

■ *Section 8*
Bulwarks, guard rails and other means for the protection of crew

8.1 General

8.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed freeboard and superstructure decks and first tier deckhouses. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by 8.2 and 8.4 respectively. Special consideration will be given to cases where this height would interfere with the normal operation of the craft.

8.1.2 The freeing arrangements in bulwarks are to be in accordance with Section 9.

8.1.3 Where appropriate, special consideration will be given to the provision of guard-wires in lieu of bulwarks or guard rails.

8.1.4 Where wire ropes are fitted, adequate devices are to be provided to ensure their tautness.

8.1.5 Where stanchions are fitted, every third stanchion is to be supported by a bracket or stay.

8.1.6 A proper step arrangement is to be provided in way of obstructions such as pipe lines, etc.

8.2 Bulwark construction

8.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these bulwark stays is not to be greater than 1,83 m. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for cargo gear, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

8.2.2 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the craft, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding that considered effective (*see* Pt 6, Ch 3,1.10, Pt 7, Ch 3,1.11 and Pt 8, Ch 3,1.7 for steel, aluminium alloy and composite construction respectively) may also be included. The free edge of the stay is to be stiffened.

8.2.3 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

8.2.4 The foregoing requirements do not allow for any loading from deck cargoes.

8.3 Openings in bulwarks

8.3.1 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

8.4 Guard rails

8.4.1 The opening below the lowest course of guardrails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of craft with rounded gunwales, the guard rail supports are to be placed on the flat of the deck.

8.4.2 Satisfactory means, in the form of guard rails, lifelines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew in getting to and from their quarters, the machinery space and all other parts used in the necessary work of the craft.

8.4.3 Chains are only permitted in short lengths in way of access openings.

8.4.4 Where permitted by the National Authority, gangways or walkways may be omitted on craft operating within **Service Groups G1** or **G2**. However, lifelines are to be provided on flush deck craft, or where the cargo hatch coamings are less than 600 mm high.

Section 9
Deck drainage

9.1 General

9.1.1 Where bulwarks on the weather portions of freeboard or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.2 Freeing port area

9.2.1 The minimum freeing area on each side of the craft for each well on the freeboard deck or raised quarter deck, where the sheer in the well is not less than the standard sheer required by the *International Convention on Load Lines*, 1966, is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less:
area required = $0{,}7 + 0{,}035l$ m^2

(b) where the length, l, exceeds 20 m
area required = $0{,}07l$ m^2
l need not be taken greater than $0{,}7L_{\mathrm{L}}$, where L_{L} is the length of the craft as defined in Ch 1,6.2.

9.2.2 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

9.2.3 The minimum freeing area for each well on a first tier superstructure is to be half the area calculated from 9.2.1.

9.2.4 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.2.5 When the deck has no sheer, the minimum freeing area for each well calculated from 9.2.1 is to be increased by 50 per cent. Where the sheer is less than the standard the percentage shall be obtained by linear interpolation. The freeing area is to be spread along the length of the well.

9.2.6 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed ten per cent of the bulwark area.

9.2.7 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small craft, credit can be given for bollard and fairlead openings where these extend to the deck.

9.2.8 Where a craft fitted with bulwarks has a continuous trunk, or hatch side coamings that are continuous, or substantially continuous, the minimum freeing area is to be not less than 20 per cent of the total bulwark area where the width of trunk or hatchway is 0,4B or less, and not less than 10 per cent of the total bulwark area when the width of the trunk or hatch is 0,75B or greater. The freeing area required for an intermediate width of trunk or hatch is to be obtained by linear interpolation.

9.2.9 Where the trunk referred to in 9.2.8 or its equivalent is included in the calculation of freeboard, open rails are to be fitted for at least 50 per cent of the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the bulwark area. The freeing area is to be placed in the lower part of the bulwark.

9.2.10 Where a deckhouse has a breadth less than 80 per cent of the beam of the craft, or the width of the side passageways exceed 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or greater than 80 per cent of the beam of the craft, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the craft, this arrangement is considered as two wells, before and abaft the deckhouse.

9.2.11 Adequate provision is to be made for freeing water from superstructures which are open at either or both ends and from all other decks within open or partially open spaces in which water may be shipped and contained.

9.2.12 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures, deckhouses and deck cargo arrangements, etc., in which water may be shipped and trapped. Deck gear, particularly on fishing craft, is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing ports.

9.2.13 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3 Free flow area

9.3.1 The effectiveness of the freeing port area in bulwarks of craft not fitted with a continuous deck obstruction, depends on the free flow across the deck.

9.3.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

9.3.3 The provision of freeing area in bulwarks is to be related to the net free flow area as follows:

(a) If the free flow area is equal to, or greater than the freeing port area calculated from 9.2.8 when the hatchway coamings are continuous, then the minimum freeing area calculated from 9.2.1 is sufficient.

(b) If the free flow area is less than the freeing port area calculated from 9.2.1, then the minimum freeing area is to be that calculated from 9.2.8.

(c) If the free flow area is less than the freeing port area derived from (a) but greater than that derived from (b), the minimum freeing area, F, in the bulwark is to be obtained from the following formula:

$$F = F_1 + F_2 - f_p \quad m^2$$

where

F_1 = minimum area from 9.2.1

F_2 = minimum area from 9.2.8

f_p = total net area of passages and gaps between hatchways, superstructures and deckhouses (the free flow area).

9.4 Scupper arrangements

9.4.1 Scuppers, sufficient in number and size to provide effective drainage, are to be fitted in all decks.

9.4.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

9.4.3 Scuppers and discharges which drain spaces below the freeboard deck, or spaces within intact superstructures or deckhouses on the freeboard deck fitted with efficient weathertight doors, may be led to the bilges in the case of scuppers, or to suitable sanitary tanks in the case of sanitary discharges. Alternatively, they may be led overboard provided that:

(a) the freeboard is such that the deck edge is not immersed when the craft heels to 5°, and

(b) the scuppers are fitted with a positive control valve or automatic non-return valve at the shell preventing water from passing inboard.

9.4.4 In craft where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle or cargo spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. The scupper area will require to be increased if the design capacity of the drencher system exceeds the Rule required capacity by 10 per cent or more. After installation, the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build up of water on the deck. The scuppers are to be led inboard to tanks or, alternatively they may be led overboard providing they comply with 9.4.3(a) and (b). Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (water contaminated with petrol or other flammable substance is not to be drained to machinery spaces or any other space where a source of ignition may be present) and the capacity of the tanks is to be sufficient to hold approximately 10 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided. The mouth of the scupper is to be protected by bars.

9.4.5 Scupper pipes from the weather decks discharging overboard below or near the waterline are to be provided with a non-return valve or positive control valve. Where the scupper pipes are of substantial construction, having a wall thickness of not less than that of the side shell plus 2 mm, the non-return valve or positive control valve may be omitted.

9.4.6 For the use of non-metallic pipe, *see* Pt 15, Ch 1,8.

9.5 Large freeing port openings

9.5.1 Where the height of freeing ports is greater than 230 mm, vertical bars spaced approximately 230 mm apart may be accepted, as an alternative to a horizontal rail, to limit the height of the freeing port. Other equivalent arrangements will be specially considered.

■ *Section 10*
Cabin sole and lining

10.1 General

10.1.1 Cabin soles are to be fitted and secured in such a manner as to provide access to the structure and fittings below.

10.1.2 The cabin fittings and linings against the side of the craft are to be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.1.3 For fire protection requirements for cabin fittings and linings, *see* Part 17.

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the craft be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.3 Fire aspects

10.3.1 For information and plans required, *see* Part 17.

■ *Section 11*
Ventilators

11.1 General

11.1.1 This Section provides requirements for ventilators and the ventilation of all craft.

11.1.2 The requirements conform, where relevant, with those of the *International Convention on Load Lines, 1966*. Reference is also to be made to any additional requirements of the National Authority of the country in which the craft is to be registered and to the relevant regulations of the *International Convention for the Safety of Life at Sea, 1974* and applicable amendments.

11.1.3 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

11.1.4 The scantlings of ventilators exposed to the weather are to be equivalent to those of the adjacent deck or bulkhead. Where the height of the ventilator exceeds that required by 11.5.1, the thickness may be gradually reduced above that height to a minimum which will be specially considered dependent on the material of construction. Ventilators are to be adequately stayed.

11.1.5 Ventilators from deep tanks and tunnels passing through 'tween decks are to have scantlings suitable for withstanding the pressures to which they may be subjected, and are to be made watertight.

11.1.6 For the requirements for fire precautions on cargo and passenger craft, *see* Part 17.

11.1.7 Adequate ventilation is to be provided throughout the craft.

11.1.8 For the requirements for yachts, *see also* Part 4.

11.2 Accommodation spaces

11.2.1 Accommodation spaces are to be protected from gas or vapour fumes from machinery, exhaust and fuel systems in accordance with Ch 2,4.7, *see also* Part 17.

11.3 Machinery spaces

11.3.1 In addition to the requirements of this Section, a filter coalescer is to be fitted to the machinery space air intakes to remove fine spray where:

- Intakes are fitted in exposed positions on the weather deck; or
- intakes are large; or
- coaming height is reduced; or
- as required by the engine manufacturer.

Special consideration will be given to alternative arrangements for craft operating within service groups G1–G3, *see also* Part 9.

11.3.2 In general, ventilators necessary to continuously supply the machinery space or the emergency generator room shall have coamings of sufficient height to comply with 11.4.1, without having to fit weathertight closing appliances.

11.3.3 Where it is not practical to comply with 11.3.2 due to ship size and arrangement, lesser heights for machinery space and emergency generator room ventilator coamings, fitted with weathertight closing may be permitted by the Administration in combination with other suitable arrangements to ensure an uninterrupted, adequate supply of ventilation to these spaces.

11.4 Closing appliances

11.4.1 All ventilator openings are to be provided with efficient weathertight closing appliances unless:

(a) The height of the coaming is greater than 4,5 m above the deck at Position 1.
(b) The height of the coaming is greater than 2,3 m above the deck at Position 2.

11.4.2 In order to limit the fire growth potential in every space of the ship, the main inlets and outlets of all ventilation systems shall be capable of being closed from outside the spaces being ventilated. The means of closing shall be easily accessible as well as be prominently and permanently marked and shall indicate whether the inlet or outlet is open or closed. Battery room ventilators are to be fitted with a means of closing only when:

(a) the battery room does not open directly onto an exposed deck; or
(b) the ventilation opening for the battery room is required to be fitted with a closing device according to the Load Line Convention; or
(c) the battery room is fitted with a fixed gas fire-extinguishing system.

11.4.3 Closing appliances are to be permanently attached to the ventilator coaming.

11.4.4 Where, in ferries, ventilators are proposed to be led overboard in an enclosed 'tween deck, the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the main vehicle deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the craft.

11.4.5 Mushroom ventilators closed by a head revolving on a centre spindle (screw down head) are acceptable in Position 2, and also in sheltered positions in Position 1, but the diameter is not to exceed 300 mm if situated within the forward $0,25L_L$.

11.4.6 Mushroom ventilators with a fixed head and closed by a screw down plate (screw down cover) may be accepted in exposed positions within the forward $0,25L_L$ up to a diameter of 750 mm.

11.4.7 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged gasketed covers secured by bolts or toggles. They are preferably to face aft or athwartships and are to be fitted with a suitable means of preventing ingress of water and spray when open in the form of louvres, baffles, screens or an equivalent arrangement.

11.4.8 Reference is to be made to Section 1 concerning down flooding through ventilators which do not require closing appliances due to their coaming height being in accordance with 11.4.1.

11.5 Effective coaming heights

11.5.1 The height of ventilator coamings exposed to the weather is to be as high as practicable, with a minimum height of 600 mm in Position 1 and 450 mm in Position 2. In particularly exposed positions, the height of coamings may be required to be increased or self closing devices may be required.

11.5.2 Reduced coaming heights may be considered for ventilators which are not required for the operation of the craft at sea, provided that operational procedures are in place and a notice is fitted to the ventilator to ensure that the closing device is closed whilst the craft is at sea.

11.5.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

11.5.4 Where wall ventilators are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

11.6 Drainage arrangements

11.6.1 Ventilators are to be provided with suitable drainage arrangements, particularly where an internal baffle is fitted, *see* 11.5.4.

■ *Section 12* Air and sounding pipes

12.1 General

12.1.1 Air and sounding pipes are to comply with the requirements of Pt 15, Ch 2,11.

12.1.2 The minimum wall thickness of steel and aluminium alloy air pipes in positions indicated in 12.2.1 is to be taken as:

t_p = $0{,}03d_p + 3{,}6$ mm with a maximum of 8,5 mm

where

t_p = wall thickness of air pipe, in mm

d_p = external diameter of air pipe, in mm.

12.1.3 The pipe material is to be compatible with the craft construction material.

12.1.4 Composite pipes may be acceptable for use on composite craft and will be specially considered.

12.1.5 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

12.1.6 For the requirements for yachts, *see also* Part 4.

12.2 Height of air pipes

12.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 450 mm on the freeboard deck;
- 300 mm on the superstructure deck;

these heights being measured above deck sheathing, where fitted.

12.2.2 Lower heights may be approved in cases where these are essential for the working of the craft, provided that the design and arrangements are otherwise satisfactory.

12.2.3 An increase in the height of air pipes may be required or recommended by individual Administrations when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc. This may entail an increase in tank scantlings and will be specially considered.

12.2.4 Air pipes are generally to be led to an exposed deck. Alternatively, air pipes from cofferdams or void spaces may terminate in the enclosed ’tween deck space on main vehicle decks, provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

12.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the summer load waterline.

12.3 Closing appliances

12.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water.

12.3.2 Exposed air pipes in positions 1 and 2 are to be provided with approved automatic closing appliances.

■ *Section 13* Particular requirements for multi-hull craft

13.1 General

13.1.1 In addition to the general requirements given in this Chapter, this Section gives particular requirements for multi-hull craft.

13.2 Multi-hull craft escape hatches

13.2.1 Multi-hull craft are to be provided with a suitable means of escape from each accommodation compartment between watertight bulkheads in the event of inversion of the craft.

13.2.2 Where the requirement given in 13.2.1 is achieved by means of escape hatches in the hull, these are to be fitted in the inboard side of each hull, or in the transom, with the lowest side of the opening at a minimum of 600 mm above the waterline in both the upright and inverted conditions of the craft. Hatch openings are to be a minimum of 450 mm x 450 mm and a maximum of 600 mm x 600 mm.

13.2.3 Escape hatch frames and covers may be of steel, aluminium alloy or FRP construction and are to be of equivalent strength to the unpierced hull side or transom in which they are fitted.

13.2.4 Hatch covers are to be weathertight when closed and the means of securing the hatch cover are to be such that weathertightness can be maintained in any sea condition.

13.2.5 Hydrostatic pressure tests are to be carried out to confirm that the proposed construction, when fitted in the hull, is able to withstand a pressure of four times the design pressure and remain watertight.

13.2.6 Hatch covers are to be flush with the hull and substantially hinged. Where fitted in the inboard side of the hull, the hinges are to be on the forward side.

13.2.7 Escape hatches are to be capable of being opened from both sides. Handles on the outside are to be suitably protected from damage or inadvertent opening.

13.3 Portlights

13.3.1 Where it is proposed to fit portlights in the hulls of wave-piercing and other non-conventional multi-hull craft, the arrangements will be specially considered.

■ *Section 1* General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable only for use in reasonably sheltered conditions or in emergencies. If the equipment is intended to be used during operations in the open sea, or if the sea or weather conditions in the service area are subject to unusual hazards, e.g. typhoons, etc., the equipment will be specially considered in each case.

1.1.2 Where the Equipment Number exceeds 1140 the equipment is to be in accordance with Pt 3, Ch 13 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Symbols

1.3.1 The following symbols are used in this Chapter, unless otherwise stated:

b_i = mean breadth of deckhouse or superstructure tier, in metres

h_i = mean height of deckhouse or superstructure tier, in metres

A = area, in m^2, in profile view of the hull, superstructure and deckhouses above the design waterline. Deckhouses with breadth less than B/4 are to be ignored

B_o = the greatest moulded breadth, in metres, or for craft of composite construction, the extreme breadth excluding rubbing strakes or other projections

B_1 = the greatest breadth of the outer hulls of a multi-hull craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

B_2 = the greatest breadth of the centre hull in trimaran type craft, in metres. It is to be measured between the points of intersection of the extension of the hull sides to the normal line of the wet deck

D_h = the sum of bi hi cos qi for all deckhouses and superstructures tiers

G_A = air gap, as defined in Pt 5, Ch 1

α_1 = for multi-hull craft is the distance in metres, from the underside of the cross-deck structure to the underside of the first tier of deckhouse or superstructure for mono-hull craft is the distance in metres, from the waterline to the underside of the first tier of deckhouse or superstructure

θ_i = angle of inclination aft, of tier of deckhouse front, with a line perpendicular to the static load waterline

Δ = loaded displacement, in tonnes.

1.4 Character of classification

1.4.1 To entitle a craft to the figure **1** in its character of classification, equipment in accordance with the requirements of this Chapter is to be provided. The regulations governing assignment of the character figure **1** for equipment are given in Pt 1, Ch 2,3.

1.4.2 For craft intended to be operated only in suitable areas or conditions which have been agreed by the Committee, as defined in Pt 1, Ch 2,3.5, equipment differing from these requirements may be approved if considered suitable for the particular service on which the craft is to be engaged.

1.4.3 Where the Committee has agreed that anchoring and mooring equipment need not be fitted in view of the particular service of the ship, the character letter **N** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.4 Where the ship is intended to perform its primary designed service function only while it is anchored, moored, towed or linked, the character letter **T** will be assigned, *see also* Pt 1, Ch 2,3.2.2.

1.4.5 For classification purposes the character figure **1**, or either of the character letters **N** or **T**, are to be assigned.

■ *Section 2* Equipment Number

2.1 Equipment Number

2.1.1 The anchoring and mooring equipment is based on an Equipment Number, *EN*, which is to be calculated as given in 2.1.2 to 2.1.4.

2.1.2 **Mono-hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1) + 0{,}1A$

2.1.3 **Catamaran, Swath, SES and other twin hull craft**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + 2G_a\,B_1) + 0{,}1A$

2.1.4 **Trimarans**

$EN = \Delta^{2/3} + 2\,(D_h + B_o\,\alpha_1 + G_a\,(2B_1 + B_2)) + 0{,}1A$

2.2 Novel craft

2.2.1 Where a craft is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

Section 3 Service group factors

3.1 General

3.1.1 The masses of anchors and the diameters and lengths of chain cable required by Table 5.5.1 and Table 5.6.1 respectively are for craft in **Service Group G4**.

3.2 G1 craft

3.2.1 For craft in **Service Group G1**, the equipment is generally to be that required for craft in **Service Group G2**; proposals for further reductions will be specially considered.

3.3 G2, G2A, G3 and G4 craft

3.3.1 For craft in **Service Groups G2**, **G2A**, **G3**, and **G4**, the mass of the anchor required by Table 5.5.1 may be multiplied by the following factors:

Service Group G2	0,60
Service Group G2A	0,65
Service Group G3	0,73
Service Group G4	1,00

3.3.2 The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Table 5.5.1.

3.3.3 Towlines and mooring lines are to be those required by Table 5.7.1 corresponding to the equipment number as determined from Section 2.

3.3.4 For service craft on particular duties, a further reduction in the mass of the anchor may be given in accordance with Section 4.

3.4 G5 craft

3.4.1 Craft in **Service Group G5** are considered for the purposes of this Chapter to be unrestricted in their service, and the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships.

3.5 G6 craft

3.5.1 **Service Group G6** covers yachts and patrol craft having unrestricted service.

3.5.2 For yachts, the mass of the anchors required by Table 5.5.1 may be multiplied by the craft type factor indicated in Section 4. The length and diameter of chain cable are to be those required by Table 5.6.1 corresponding to the reduced anchor mass given in Section 4.

3.5.3 For patrol craft, the equipment is to be in accordance with Pt 3, Ch 13 of the Rules for Ships for unrestricted service.

Section 4 Craft type factors

4.1 General

4.1.1 The mass of the anchors required by Table 5.5.1 and corrected for service group factors in accordance with Section 3 (where applicable), are to be corrected by the craft type factors indicated in this Section.

4.2 Craft type factors

4.2.1 **Yachts** with an Equipment Numeral, *EN*, of less than or equal to 220 as determined in 2.1, may have the mass of the anchors as required by Table 5.5.1 reduced by the craft type factor, k_y, in accordance with the following:

$$k_y = \frac{EN}{500} + 0{,}56$$

4.2.2 For yachts with an Equipment Numeral, *EN*, in excess of 220, the craft type factor, k_y, is to be taken as unity.

4.2.3 **Pilot and Patrol** craft operating within **Service Group G1**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 220 as determined in 2.1, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p1}, in accordance with the following:

$$k_{p1} = \frac{EN}{980} + 0{,}28$$

4.2.4 **Pilot and patrol** craft operating within **Service Group G2**, and which do not normally anchor in the course of their duties, with an Equipment Numeral *EN* of less than or equal to 100 as determined in 2.1.2, may have the mass of the anchor as required by Section 3 reduced by the craft type factor, k_{p2}, in accordance with Table 5.4.1.

Table 5.4.1 Craft type factor

Equipment Numeral, *EN*	Craft type factor, k_{p2}
≥ 5 ≤ 40	0,8
> 40 ≤ 100	0,9
> 100	1,0

Section 5
Anchors

5.1 General

5.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

5.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in Table 5.5.1 is to be increased by 33 per cent.

5.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

5.1.4 Craft other than yachts are to be provided with a single anchor on board which must be ready for immediate use.

5.1.5 In addition, the craft is to be supplied with one spare anchor located at each of the ports on its regular scheduled service, or alternatively the spare anchor may be carried on board.

5.1.6 **Yachts** are to be provided with two anchors on board. Each anchor must have the rule length of chain cable attached. Only one anchor is required to be ready for immediate deployment, i.e. around the capstan. The masses of anchors may be of the following combinations:

(a) The mass of the first anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned. The mass of the second anchor is to be not less than 70 per cent of the Rule value for the type concerned.

(b) The mass of each anchor is to be not less than 90 per cent of the Rule value for the type of anchor concerned.

5.1.7 The fitting of a single anchor on board yachts will be specially considered. The mass of the single anchor is to be not less than 100 per cent of the Rule value for the type of anchor concerned.

Table 5.5.1 Anchors

Equipment number		High holding power bower anchors	
Exceeding	Not exceeding	Number of anchors	Mass of anchor, in kg
—	5	1	11
5	10	1	13
10	15	1	17
15	20	1	22
20	25	1	27
25	30	1	32
30	35	1	37
35	40	1	44
40	45	1	52
45	50	1	59
50	70	1	80
70	90	1	117
90	110	1	154
110	130	1	197
130	150	1	240
150	175	1	292
175	205	1	360
205	240	1	428
240	280	1	495
280	320	1	585
320	360	1	675
360	400	1	765
400	450	1	855
450	500	1	968
500	550	1	1080
550	600	1	1193
600	660	1	1305
660	720	1	1440
720	780	1	1575
780	840	1	1710
840	910	1	1845
910	980	1	1980
980	1060	1	2138
1060	1140	1	2295

5.1.8 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal craft use. In such cases suitable tests may be required.

5.1.9 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

5.2 Materials

5.2.1 The requirements for anchor materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

5.2.2 Anchors made of stainless steels or aluminium alloy may be acceptable subject to special consideration.

5.2.3 Where aluminium alloy anchors are proposed, due consideration is to be given to the compatibility of such anchors with the materials of the chain cable, anchor shackle, etc., in order to avoid galvanic corrosion.

5.3 Testing

5.3.1 Testing of anchors is to be carried out in accordance with Chapter 10 of the Rules for Materials.

5.3.2 For holding power testing requirements relating to high holding power anchors, *see* Ch 10,1.7 of the Rules for Materials.

5.4 Anchor shackle

5.4.1 Steel anchor shackles are to be forged or cast steel of approved manufacturer.

5.5 Anchor stowage

5.5.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

5.5.2 Hawse pipes and anchor pockets are to be in accordance with 9.3. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

5.6 Super high holding power (SHHP) type anchors

5.6.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

5.6.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

5.6.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

5.7 Tolerances

5.7.1 The mass of each high holding power anchor given in Table 5.5.1 is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

5.8 Identification

5.8.1 Identification of anchors which have been tested is to be in accordance with Ch 10,1.4 of the Rules for Materials.

■ *Section 6* Anchor cable

6.1 General

6.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

6.1.2 For each anchor required to be carried on board, *see* 5.1.6, a length of anchor cable, as indicated in Table 5.6.1, is to be provided.

6.2 Chain cable

6.2.1 The diameter of stud link chain cable is to be as indicated in Table 5.6.1.

6.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by Table 5.6.1.

6.2.3 Chain cables may be of mild steel, special quality steel or extra quality steel in accordance with the requirements of Ch 10 of the the Rules for Materials, and are to be graded in accordance with Table 5.6.2.

6.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

6.2.5 In addition to 6.2.3 special consideration will be given to the use of chain cable of stainless steel. Stainless steel is to be of a suitable type, details of which are to be submitted for consideration.

6.2.6 The form and proportion of links and shackles are to be in accordance with Chapter 10 of the Rules for Materials.

Table 5.6.1 Chain cable

Mass of HHP bower anchor, in kg	Length of chain cable, in metres	Stud link chain cable diameter, in mm		
		Mild steel (Grade:1 or U1)	Special quality steel (Grade:U2)	Extra special quality steel (Grade:U3)
11	55	8	–	–
13	55	8	–	–
17	55	8	–	–
22	55	9	–	–
27	55	9	–	–
32	82,5	9	–	–
37	82,5	11,2	–	–
44	82,5	11,2	–	–
52	110	11,2	–	–
59	110	12,5	–	–
80	110	12,5	–	–
117	110	14	12,5	–
154	110	16	14	–
197	137,5	17,5	16	–
240	137,5	19	17,5	–
292	137,5	20,5	17,5	–
360	137,5	22	19	–
428	165	24	20,5	–
495	165	26	22	20,5
585	165	28	24	22
675	192,5	30	26	24
765	192,5	32	28	24
855	192,5	34	30	26
968	192,5	36	32	28
1080	220	38	34	30
1193	220	40	34	30
1305	220	42	36	32
1440	220	44	38	34
1575	220	46	40	36
1710	247,5	48	42	36
1845	247,5	50	44	38
1980	247,5	52	46	40
2138	247,5	54	48	42
2295	247,5	56	50	44

Table 5.6.2 Grades of steel for use as chain cable

Grade	Material	Tensile strength (N/mm^2)
U1	Mild steel	300 – 490
U2 (a)	Special quality steel (wrought)	490 – 690
U2 (b)	Special quality steel (cast)	490 – 690
U3	Extra special quality steel	690 min

6.3 Testing

6.3.1 Chain cable with a diameter of 12,5 mm or above is to be certified by Lloyd's Register (hereinafter referred to as 'LR'). Chain cable with a diameter below 12,5 mm is to be certified by a recognised testing establishment.

6.3.2 All chain cables are to be tested at establishments and on machines recognised by the Committee and under the supervision of LR's Surveyors or other Officers recognised by the Committee, and in accordance with Chapter 10 of the Rules for Materials.

6.3.3 Test certificates showing particulars of size and weight of cable and of the test loads applied are to be furnished. These certificates are to be examined by the Surveyors when the cables are placed on board the craft.

6.4 Wire rope

6.4.1 When the Equipment Number does not exceed 500 for craft in **Service Groups G1**, **G2**, **G2A** and **G3**, steel wire rope may be accepted in lieu of chain cable under the following conditions:

(a) A length of chain of the diameter specified in Table 5.6.1 is to be fitted to the anchor. The total length of chain is to be not less than 10 per cent of the total required by Table 5.6.1. In no case is the length of chain attached to an anchor to be less than 9 metres.
(b) The wire rope used in lieu of chain cable is to have a breaking load of not less than that of the chain cable it replaces.
(c) The combined length of the chain cable specified in (a) and the wire is to be not less than the length of chain cable required by Table 5.6.1.
(d) Thimbles are to be fitted at both ends of the wire rope, as appropriate.
(e) Suitable precautions are to be taken to reduce the wear on the wire rope at fairleads, etc.

6.4.2 Steel wire ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5 Fibre rope

6.5.1 When the Equipment Number does not exceed 100, polyamide (or other equivalent synthetic fibre) rope may be accepted in lieu of wire rope, subject to compliance with 6.4.1(a) to (d).

6.5.2 Fibre ropes are to be manufactured, tested and certified as required by Chapter 10 of the Rules for Materials.

6.5.3 Synthetic fibre ropes are to be ultra-violet inhibited as necessary, dependent upon their type.

6.6 Cable clench

6.6.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment is to have a working strength of not less than 10 per cent of the breaking strength of the chain cable, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

6.7 Cable stopping and release arrangements

6.7.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outwith the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

6.8 Cable locker

6.8.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

6.8.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

6.8.3 Chain lockers and spurling pipes are to be watertight up to the exposed weather deck and the space is to be efficiently drained. However, bulkheads between separate chain lockers, or which form a common boundary of chain lockers, need not be watertight.

6.8.4 Where means of access is provided to the chain locker, it is to be closed by a substantial cover and secured by closely spaced bolts.

6.8.5 Where a means of access to spurling pipes or cable lockers is located below the weather deck, the access cover and its securing arrangements are to be in accordance with ISO 5894-1999, or an equivalent National Standard acceptable to LR, recognised standards or equivalent for watertight manhole covers. Butterfly nuts and/or hinged bolts are prohibited as the securing mechanism for the access cover.

■ *Section 7* Mooring ropes and towlines

7.1 Mooring ropes

7.1.1 Craft under 90 m in length are to be equipped with mooring ropes in accordance with Table 5.7.1.

7.1.2 The lengths of individual mooring lines in Table 5.7.1 may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

7.2 Materials

7.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of Chapter 10 of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

7.3 Testing and certification

7.3.1 Mooring ropes are to be tested and certified in accordance with Chapter 10 of the Rules for Materials.

7.4 Towlines

7.4.1 Towlines are not required for classification other than for craft which are required to comply with the *IMO Code of Safety for High Speed Craft.* The details given in Table 5.7.1 are for guidance purposes only.

7.5 Bollards, fairleads and bull rings

7.5.1 Means are to provided to enable mooring lines to be adequately secured on board the craft. It is recommended that the total number of suitably placed bollards on either side of the craft and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended. Attention is drawn to the existence of a number of National Standards for bollards and fairleads, and to the importance of ensuring that their seating arrangements, including the supporting hull structure, are efficiently constructed and adequate for the intended loads.

7.6 Towing requirements

7.6.1 Craft which are to comply with the *IMO Code of Safety for High Speed Craft* are to be provided with adequate arrangements to enable the craft to be towed in the worst intended environmental conditions. It is recommended that other craft comply with this requirement.

Table 5.7.1 Towlines and mooring lines

Equipment Number		Towline, *see* Notes		Mooring lines		
Exceeding	Not exceeding	Minimum length, in metres	Minimum breaking strength, in kN	Number of lines	Minimum length of each line, in metres	Minimum breaking strength, in kN
–	5	90	19,9	2	55	13,9
5	10	90	22,5	2	55	17,6
10	15	90	27,7	2	55	21,5
15	20	90	32,9	2	55	24,5
20	25	110	38,1	2	55	26,6
25	30	110	43,3	2	55	28,2
30	35	110	48,5	2	55	29,6
35	40	135	53,7	2	55	30,8
40	45	135	58,9	2	70	31,8
45	50	135	64,1	2	85	32,7
50	70	180	71,0	2	100	35,5
70	90	180	82,1	2	100	39,3
90	110	180	93,2	2	110	43,1
110	130	180	104,3	2	110	46,6
130	150	180	115,3	2	120	50,2
150	175	180	127,8	2	120	54,4
175	205	180	143,0	2	120	58,8
205	240	180	161,1	2	120	64,2
240	280	180	181,8	3	120	71,1
280	320	180	204,0	3	140	78,5
320	360	180	226,1	3	140	85,8
360	400	180	248,3	3	140	93,2
400	450	180	273,2	3	140	100,5
450	500	180	300,9	3	140	107,9
500	550	180	328,6	4	160	112,8
550	600	180	356,3	4	160	117,7
600	660	180	386,8	4	160	122,6
660	720	180	420,1	4	160	127,5
720	780	180	453,3	4	170	132,4
780	840	180	486,5	4	170	137,3
840	910	180	522,5	4	170	142,2
910	980	180	561,3	4	170	147,1
980	1060	180	602,9	4	180	156,9
1060	1140	180	647,2	4	180	166,7

NOTES
1. Towline specified for guidance only, *see* 7.4.1.
2. Wire ropes used for towlines and mooring lines are generally to be of a flexible construction with not less than:
   144 wires in six strands with seven fibre cores for strengths up to 490 kN
   222 wires in six strands with one fibre core for strengths exceeding 490 kN
   The wires to be laid around the fibre centre of each strand are to be up in not less than two layers.
3. Wire ropes for towlines and mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.
4. Irrespective of strength of requirements, no fibre rope is to be less than 12 mm diameter.

7.7 Towing bitts

7.7.1 Where towage is to be from more than one point a suitable bridle is to be provided.

7.7.2 Details of the structural scantlings, arrangements, loadings and design assumptions for the towing bitts are to be submitted for consideration.

7.7.3 The towing arrangements should be such that damage to the towline or bridle from abrasion is minimised.

7.8 Mooring winches

7.8.1 Mooring winches where provided are to be suitable for the intended purpose. Supports under the winches are to be to the Surveyor’s satisfaction.

7.8.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum, *see also* 7.5.1.

■ *Section 8* Windlass design and testing

8.1 General

8.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the craft. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 Windlasses may be hand or power operated, subject to the requirements of 8.2.3.

8.1.3 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.4 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.5 On craft equipped with anchors having a mass of over 50 kg windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.2 Windlass design

8.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull of:
$28{,}5\, d_c^2$ N – for Grade U1 chain, with $d_c < 14$ mm
$37{,}5\, d_c^2$ N – for Grade U1 chain, with $d_c \geq 14$ mm
$42{,}5\, d_c^2$ N – for Grade U2 chain
$47{,}5\, d_c^2$ N – for Grade U3 chain
over a period of $0{,}12 L_c$ minutes. The test period need not be taken longer than 30 minutes
where
d_c is the chain diameter, in mm
L_c is the total length of chain cable on board, in metres, as given by Table 5.6.1.

(b) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:
  (i) short-term pull:
  1,5 times the continuous duty pull as defined in 8.2.1(a).
  (ii) anchor breakout pull:
  $12{,}18 W_a + 7{,}0 L_c\, d_c^2/100$ N
where
W_a is the mass of bower anchor(kg) as given in Table 5.5.1.

(c) In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:
$K_b\, d_c^2\, (44 - 0{,}08 d_c)$ N
where
K_b = 7,85 for Cable Grade U1
= 11,00 for Cable Grade U2
= 15,70 for Cable Grade U3.

(d) Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position, the following notice is to be displayed adjacent to the windlass control position, and at clearly visible locations on the bridge if the windlass can be operated remotely:
'The brake is rated to permit controlled descent of the anchor and chain only. The chain stopper is to be used at all times whilst riding at anchor.'
The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

8.2.2 Windlass performance characteristics specified in 8.2.1 and 8.3.2 are based on the following assumptions:
(a) one cable lifter only is connected to the drive shaft,
(b) continuous duty and short term pulls are measured at the cable lifter,
(c) brake tests are carried out with the brakes fully applied and the cable lifter declutched,
(d) the probability of declutching a cable lifter from the motor with its brake in the off position is minimised,
(e) hawse pipe efficiency assumed to be 70 per cent.

8.2.3 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of 1,0. Alternatively, unlimited hours with a nominal load spectrum factor of 0,8 can be applied.

8.2.4 Where the available input torque exceeds the torque required for anchor breakout, torque overload protection is to be fitted.

8.2.5 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided.

8.2.6 The maximum calculated stress from the load cases stated in Table 5.8.1 are not to exceed the permissible stress limits stated in Table 5.8.2.

8.2.7 The following criteria are to be used for gearing design:
(a) Torque is to be based on the performance criteria specified in 8.2.1.
(b) The use of an equivalent torque, T_{eq}, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.

(c) The application factor for dynamic strength calculation, K_A, is to be 1,15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be 1,5 x T_n, where T_n is the nominal torque.
(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International Standard acceptable to LR, are to be 1,5 for bending stress and 0,6 for contact stress.

8.2.8 Keyways are to be designed to a relevant National or International Standard acceptable to LR.

8.2.9 The maximum stress in brake components is not to exceed the permissible stress stated in Table 5.8.2.

8.2.10 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 15 kgf for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.2.11 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.3 Control arrangements

8.3.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.3.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions.

Table 5.8.1 Design load cases for windlass and chainstopper

Load case	Condition	Note
1	Continuous pull	*See* 8.2.1 (a)
2	Overload pull	*See* 8.2.1 (b)
3	Brake holding load	*See* 8.2.1 (c)

Table 5.8.2 Permissible stress for design load cases

Stress	Load case	
	1 and 2	3
	Permissible stress	
Tension	0,8 Y	0,9Y
Compression or bending	0,8 Y	0,9Y
Shear	0,7 Y	0,7Y
Combined	0,85 Y	0,9Y

NOTES
1. Where a component is subjected to axial tensile, axial compressive, bending or shear stress, F_c is to be calculated in the normal manner.
2. Where a component is subjected to a combination of co-existent stresses, F_c is the combined stress which is to be calculated as follows:
Combined bending and tension
$F_c = 1{,}25 f_c + f_{bt}$
Combined bending and compression
$F_c = f_c + f_{bc}$
Combined bending, tension and shear
$$F_c = \sqrt{(1{,}25\, f_t + f_{bt})^2 + 3\, f_q^2}$$
Combined bending, compression and shear
$$F_c = \sqrt{(f_c + f_{bc})^2 + 3\, f_q^2}$$

where
F_c is the calculated stress
f_t is the calculated axial tensile stress
f_c is the calculated axial compressive stress
f_{bt} is the calculated maximum tensile stress due to bending about both principal axes
f_{bc} is the calculated maximum compressive stress due to bending about both principal axes
f_q is the calculated shear stress
Y is the specified 0,2 per cent proof stress for the material

8.3.3 Wherever practical, the lever is to move in the direction of the intended movement. If this cannot be achieved, then it is to move towards the right when hauling and towards the left when paying out.

8.3.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

8.3.5 For pedal-operated brakes, the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.3.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.3.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.3.8 The push-buttons are to actuate the machinery when depressed, and stop and effectively brake the machinery when released.

8.3.9 The above-mentioned individual push-buttons may be replaced by two 'start' and 'stop' push-buttons.

8.3.10 Control systems, whether electric, pneumatic or hydraulic, are to comply with the general requirements of Pt 6, Ch 1,2.

8.4 Maintenance arrangements

8.4.1 Access is to be provided for inspection of reduction gears, bearings, brakes, etc.

8.4.2 Accessible manual lubrication points, including nipples, are to be provided for both oil and grease, as applicable.

8.4.3 Gear-boxes are to be provided with adequate access arrangements for monitoring and replacing oil.

8.5 Protection arrangements

8.5.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.5.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.5.3 Steel surfaces not protected by lubricant are to be protected by a coating in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.5.4 For arrangements of power transmission systems and relief requirements, *see* Pt 5, Ch 14,9.1 of the Rules for Ships.

8.6 Marking and identification

8.6.1 Controls are to be permanently marked for identification, unless their functions are readily apparent. If required, instructions are to be permanently marked and readily visible.

8.7 Tests and trials

8.7.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with 8.2.1 are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

8.7.2 During trials on board the craft the windlass should be shown to be capable of raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min. Where the depth of water in the trial area is inadequate, or the anchor cable is less than 82,5 m, suitable equivalent simulating conditions will be considered as an alternative.

8.8 Seatings

8.8.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor's satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

■ *Section 9* Structural details

9.1 General

9.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

9.2 Bulbous bow and wave piercing bow arrangements

9.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by Parts 6, 7 and 8 of the Rules for steel, aluminium alloy and composite materials respectively.

9.3 Hawse pipes and anchor recesses

9.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.3.2 The hawse pipes are to be of sufficient size and thickness, and arranged to give an easy lead for the cable to the windlass.

9.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see* 9.5.1. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.4 Spurling pipes

9.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers, *see* 6.8. Spurling pipes are to be provided with permanently attached closing appliances to minimise water ingress.
Examples of acceptable arrangements are:
(a) steel plates with cutouts to accommodate chain links, or
(b) canvas hoods with a lashing arrangement that maintains the cover in the secured position.

9.5 Local reinforcement

9.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

9.5.2 Supports under windlasses and winches are to be suitably reinforced.

■ *Section 1* General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of the noise and vibration on special service craft and are applied in addition to the other relevant requirements of these Rules.

1.1.2 For the purpose of these Rules, the term 'ship', unless otherwise stated, applies to Special Service Craft and Yachts.

1.1.3 Compliance with these Rules is optional.

1.1.4 These Rules provide for two alternatives:
(a) **Class Notations** which indicate that the ship has been assessed and complies with noise and vibration criteria of these Rules and that a periodic survey regime has been established for the lifetime of the ship.
(b) **Certificate of Compliance** which provides evidence that the ship has been assessed and found to comply with the noise and vibration criteria of these Rules.

1.1.5 These Rules recognise existing National and International Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters and pre-survey reviews. Inspections and measurements are to be conducted, witnessed or assessed by Lloyd's Register's Surveyors unless otherwise agreed by Lloyd's Register (hereinafter referred to as 'LR').

1.1.6 Accommodation comfort is a function of ship type and layout. These Rules address two types of ship:
(a) High-speed (e.g. surface effect ships, wave piercing catamarans, hydrofoils).
(b) Yacht (e.g. sailing yachts, motorised pleasure craft).

1.1.7 These Rules include levels of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the Builders undertake calculations of noise and vibration characteristics so that any potential problem areas can be identified and control measures implemented.

1.1.8 The sound pressure levels for audible alarms and public address systems fitted in accordance with other Sections of the Rules are to satisfy IMO Resolution A.830(19), Code on Alarms and Indicators.

1.2 Definitions

1.2.1 **Passenger spaces** are defined as all areas intended for passenger use, and include the following:
(a) Passenger cabins.
(b) Public spaces (e.g. restaurants, hospitals, lounges, reading and games rooms, gymnasiums, corridors and/or shops).
(c) Open deck recreation areas.

1.2.2 **Crew spaces** are defined as all areas intended for crew use only, and include the following:
(a) Accommodation spaces (e.g. cabins, offices, mess rooms, recreation rooms).
(b) Work spaces.
(c) Navigation spaces.

1.2.3 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.4 **Vibration level** is defined by the application of either of the two versions of the ISO 6954 Standard:
(a) Where ISO 6954:1984 is applied, the vibration level is defined as the single amplitude peak value of deck structure vibration during a period of steady state vibration, representative of maximum repetitive behaviour, in mm/s, over the frequency range 5 to 100 Hz. For frequencies below 5 Hz, the requirements for vibration levels follow constant acceleration curves corresponding to the acceleration at 5 Hz.
(b) Where ISO 6954:2000 is applied, the vibration level is defined as the overall frequency weighted r.m.s. value of vibration during a period of steady-state operation over the frequency range 1 to 80 Hz.

In general, ISO 6954-2000 is the preferred standard to be applied, however ISO 6954-1984 may be applied where there are practical difficulties in the application of ISO 6954-2000 and this has been agreed between the Owner and Builder.

1.3 Class notations

1.3.1 The class notations described in 1.3.2 to 1.3.6 provide standards for noise and vibration levels in different spaces at the time of delivery and during the ship's life if substantial changes to the machinery installation or interior arrangements are made.

1.3.2 The **PAC** (Passenger Accommodation Comfort), **CAC** (Crew Accommodation Comfort) and **PCAC** (Passenger and Crew Accommodation Comfort) notations are optional and are primarily intended to apply to passenger ships. If requested, however, any ship can be assessed for compliance, using these requirements as the basis for the assessment and a LR Certificate of Compliance issued (*see* 1.1.4(b) and 1.4).

1.3.3 The **PAC** notation indicates that the passenger accommodation meets the acceptance criteria whilst the **CAC** notation indicates that the crew accommodation and work areas meet the acceptance criteria. The **PCAC** notation indicates that the passenger and crew spaces both meet the acceptance criteria.

1.3.4 For ships which achieve the noise and vibration comfort standards specified in these Rules, the notation **PAC**, **CAC** or **PCAC** will be assigned.

1.3.5 Following the **PAC** or **CAC** notation, numerals **1**, **2** or **3** will indicate the acceptance criteria to which the noise and vibration levels have been assessed. In the case of the **PCAC** notation, two numerals will be assigned. The first will indicate the acceptance criteria for passenger accommodation, whilst the second will indicate the crew comfort criteria.

1.3.6 For particular vessels, impact insulation and transient noise in accordance with 2.5 and 2.6 together with any additional or more stringent noise and vibration criteria may be assessed within the scope of the notations where agreed between the Owner, Builder and LR.

1.4 Certificate of Compliance

1.4.1 A Certificate of Compliance records that a ship has been designed and constructed to satisfy the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements and reporting in accordance with Sections 4 and 5.

1.4.2 A Certificate of Compliance is optional and if requested, any ship can be assessed for compliance using the Rule requirements.

1.4.3 Where noise and vibration levels are at variance with those prescribed by these Rules, they will be added to the certificate for information purposes.

1.4.4 A Certificate of Compliance will be issued after the initial survey required by Section 6.

■ *Section 2*
Noise

2.1 Assessment criteria

2.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and advised to LR.

2.2 Passenger accommodation and public spaces

2.2.1 Under test conditions specified in 4.2, the applicable noise levels specified in Tables 6.2.1 and 6.2.2 should not generally be exceeded. *See* 2.2.3.

Table 6.2.1 High speed craft – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Public spaces:	Excluding shops	60	65	70
	Shops	65	68	72

Table 6.2.2 Yachts – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	53	55	58
	Superior	50	53	55
Lounges		55	58	60
Open deck recreation areas:	2nd deck from WL	72	75	79
	3rd deck from WL	63	66	70
Wheelhouse		60	62	75

NOTES
1. The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.
2. The levels may be exceeded by 3dB(A) in accommodation above the propellers for three decks above the mooring deck.
3. The levels for open deck recreation areas refer to ship generated noise only. On open deck spaces the noise generated from the effects of wind and waves can be considered separately to limits agreed between the Builder and Owner and advised to LR for the trial conditions.

2.2.2 For cabins bordering discotheques and similar entertainment areas, the deck and bulkhead sound insulation is to be sufficient to ensure that the maximum cabin noise levels are not exceeded even when high external noise levels prevail.

2.2.3 Acceptance of noise levels greater than those specified in Tables 6.2.1 and 6.2.2 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the passenger cabins, 30 per cent of the public spaces and 20 per cent of the crew cabins should exceed the relevant noise criteria by more than 3 dB(A).

2.2.4 Acoustic insulation of bulkheads and decks between passenger spaces is to be generally in accordance with the values of the weighted apparent sound reduction index, R_w, as given in Table 6.2.3, calculated using ISO 717/1. *See also* 2.2.6.

Table 6.2.3 Minimum air-borne sound insulation indices, R_w

Location		Acceptance Numeral		
		1	2	3
Passenger cabins:	Standard	40	38	37
	Superior	45	42	40
Cabin to corridor:	Standard	38	36	34
	Superior	42	40	37
Cabin to stairway:	Standard	47	45	43
	Superior	50	47	45
Cabin to public space (excluding corridoors/ stairwells and discotheques):	Standard	52	48	48
	Superior	55	50	50
Discotheques to cabins		60	60	60
Discotheques to stairwells and public spaces		52	52	52
Cabin to machinery rooms and engine casing		55	53	50

2.2.5 For the purpose of selecting acoustic sound insulation, the following sound noise levels may be used with the agreement of the Owner and Builder:
(a) Cabins – 80 dB(A).
(b) Dining Rooms – 85 dB(A).
(c) Corridors – 90 dB(A).
(d) Discotheques, Theatres, Entertainment Areas – 105 dB(A).

2.2.6 Acceptance of bulkhead and deck acoustic insulation values less than those specified in Table 6.2.3 may be considered where agreed between the Owner and Builder. Not more than 20 per cent of the interfaces tested should have airborne sound insulation indices, R_w, more than 3 dB(A) lower than the minimum specified values.

2.3 Crew accommodation and work areas

2.3.1 Under the applicable test conditions specified in 4.2, the noise levels specified in Tables 6.2.4 and 6.2.5 are not to be exceeded.

2.3.2 Crew space insulation is to comply with the requirements of IMO Resolution A.468(XII).

Table 6.2.4 Crew accommodation – Maximum noise levels in dB(A)

Location		Acceptance Numeral		
		1	2	3
Sleeping cabins, hospitals		52	55	60
Day cabins		55	60	60
Office conference rooms		55	60	65
Mess rooms, lounges, reception areas:	Within accommodation	57	60	65
	On open decks	65	70	75
Alleyways, changing rooms, bathrooms, lockers		70	75	75
NOTE The levels may be exceeded by 5dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.				

Table 6.2.5 Crew work areas – maximum noise levels in dB(A)

Location	dB(A) level
Machinery space(continuously manned) e.g. stores	90
Machinery space(not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Workshops	85
Machinery control rooms	75
Wheelhouse	65
Bridge wing, additional limits: • 250 Hz band • 500 Hz band	 68 63
Radio room	60
Galleys and pantries: • Equipment not working • Individual items at 1 metre	 75 80
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge or forecastle	110

2.4 Maximum noise levels

2.4.1 Where the measured noise level exceeds the specified criterion by 3 dB(A), or contains subjectively annoying low frequency or tonal components, the noise rating (NR) number is to be established in accordance with the graph shown in Fig. 6.2.1. This is achieved by plotting the linear octave band levels on the graph; the NR number is that NR curve to which the highest plotted octave band level is anywhere tangent. The specified criterion may be considered satisfied if the NR number does not exceed the specified A-weighted value minus 5 dB(A).

2.4.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits for crew spaces is given in IMO Resolution A.468(XII).

2.5 Impact insulation

2.5.1 Where agreed between the Owner, Builder and LR, enhanced criteria for noise levels recognising the effects of impact sound pressures may be applied in accordance with 2.5.2 to 2.5.5.

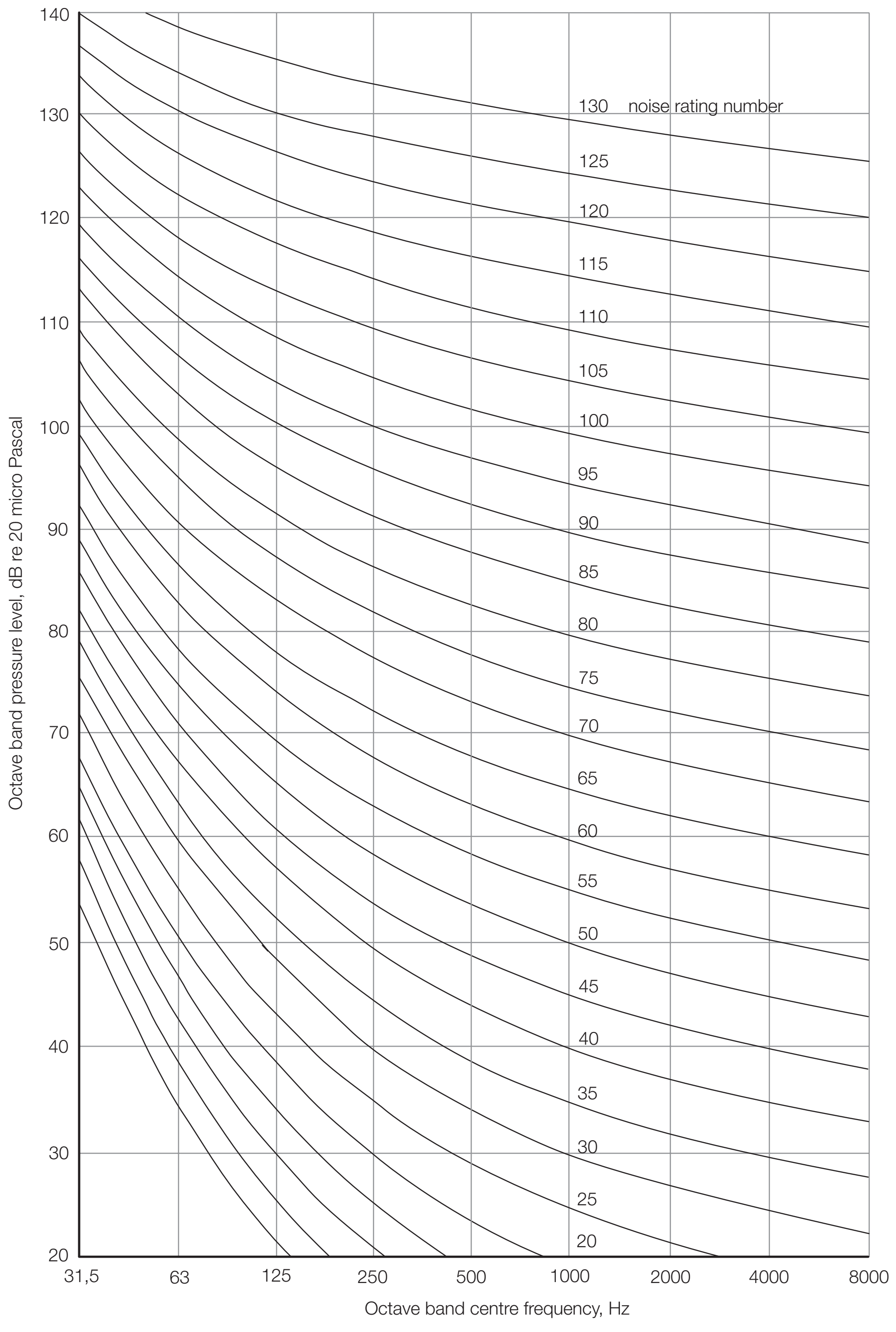


Fig. 6.2.1 Noise rating curves

2.5.2 For passenger and crew cabins located below or adjacent to dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level measured within the cabins is not to exceed 45 dB.

2.5.3 For public rooms under dance floors, stages, aerobics and gymnasium areas, jogging tracks or other areas where impact noise is generated, the normalised impact sound pressure level within the space is not to exceed 55 dB.

2.5.4 For passenger cabins, the normalised impact sound pressure level, $L_{n,w}$, calculated using ISO 717/2, is to be generally in accordance with the values stated in Table 6.2.6. *See also 2.5.5*.

Table 6.2.6 Passenger cabins normalised impact maximum sound pressure level $L_{n,w}$

Location	dB
Below decks covered with carpet and soft materials	50
Below decks covered with hard materials (such as wood, marble or similar	60
Below dance floors, theatre or sports rooms	47

2.5.5 Acceptance of normalised impact sound pressure levels greater than those specified in Table 6.2.6 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR. No more than 20 per cent of the passenger cabins tested should exceed the levels specified by more than 3 dB.

2.6 Transient noise

2.6.1 Where agreed between the Owner, Builder and LR, enhanced criteria for transient noise levels may be applied in accordance with 2.6.2.

2.6.2 The maximum sound pressure level (L_{max}) emanating from any machinery or system caused by a single event that produces a noise 'spike' compared to the reference condition sound level (such as vacuum systems or valve operations) is not to cause an increase in noise in comparison with the reference condition as below:

(a) Passenger cabins and public areas: +2 dB(A)
(b) Officer cabins: +2 dB(A)
(c) Crew cabins and public areas: +3 dB(A)

A tolerance of +1 dB(*A*) may be applied to 5 per cent of cabins and public areas in each fire zone on each deck. This criterion is generally applicable to the specified maximum noise levels for the space concerned.

■ *Section 3* Vibration

3.1 Assessment criteria

3.1.1 Where a space is occupied by both passengers and crew, the more stringent of the relevant requirements apply unless agreed between the Builder and Owner and this agreement advised to LR.

3.1.2 The limits apply to vertical, fore and aft and athwartship vibrations which are to be assessed separately.

3.1.3 Under test conditions specified in 4.2, the applicable vibration levels specified in Tables 6.3.1 to 6.3.3 should not be exceeded.

Table 6.3.1 High speed craft – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Public spaces	2,5	4,0	5,0	2,5	3,2	3,6

Table 6.3.2 Yacht – Maximum vibration levels

Standard:	ISO 6954:1984			ISO 6954:2000		
Units:	Peak velocity (5 –100 Hz)			Frequency weighted (1–80 Hz) velocity mm/s rms		
	Acceptance Numeral					
Location	1	2	3	1	2	3
Cabins and lounges	1,0	2,0	3,0	1,8	2,0	2,5
Public spaces	1,5	3,0	4,0	2,5	2,9	3,3
Open recreation decks	2,0	3,5	4,0	2,5	3,2	3,8
NOTE The vibration level may be exceeded by 0,3 mm/s in the yacht's aft body directly above the propellers.						

3.1.4 Acceptance of vibration levels greater than those specified in Tables 6.3.1 to 6.3.3 may be considered for assignment of the applicable class notation where agreed between the Owner, Builder and LR.

Table 6.3.3 Crew spaces – Maximum vibration levels

Standard	ISO 6954:1984	ISO 6954:2000
Units	Peak velocity (5–100 Hz)	Frequency weighted (1–80 Hz) velocity mm/s rms
Location		
Accommodation and navigation spaces	5,0	3,5
Work spaces	6,0	5,0

3.1.5 The vibration levels for ISO 6954:1984 are stated as peak vibration velocity amplitude. If root mean square levels are measured, each frequency component may be converted to peak vibration velocity amplitude by application of a 1,41 multiplication factor where the ISO 6954:1984 is used for assessment against Tables 6.3.1 to 6.3.3. An approximation of maximum repetitive values may be obtained for direct comparison with the graph in ISO 6954-1984 by further application of the 1,8 conversion factor as stated in the 'Interim guidelines' note of the standard.

3.2 Passenger accommodation and public spaces

3.2.1 Passenger spaces are to comply with the overall vibration levels specified in Tables 6.3.1 and 6.3.2.

3.2.2 No more than 20 per cent of all passenger spaces/areas and public spaces should exceed the relevant vibration criteria specified in Tables 6.3.1 and 6.3.2 by more than 0,3 mm/s whether using ISO 6954:2000 or ISO 6954:1984.

3.3 Crew accommodation and work spaces

3.3.1 Crew spaces are to comply with the overall vibration levels specified in Table 6.3.3.

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation as defined in 4.7 or by LR. In the former case, the measurements are to be witnessed by an LR Surveyor.

4.1.3 Subject to agreement by LR and the Owner/ Operator, the measurements may be undertaken by the Builder. In this case, the measurements are to be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 6954:1984 or ISO 6954:2000, as applicable.

4.2.2 The intended operating and loading conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys are to be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) For high speed craft and yachts, prior to measurement surveys being carried out, the ship operating condition where the worst conditions are experienced between 0 and 85 per cent maximum continuous rating of the propulsion machinery is to be determined. To establish this condition, four measurement positions are to be defined with the agreement of LR and measurements taken of the parameters of interest at ship speeds corresponding to percentages of the maximum continuous rating of the propulsion machinery increasing up to 40 per cent MCR in 10 per cent intervals and from 40 per cent in 5 per cent intervals up to the 85 per cent maximum continuous rating of the propulsion machinery. If the 85 per cent maximum continuous rating condition is found to be the worst condition, then this will form the trial operating conditions. However, if a lower speed condition is found to be worse than the 85 per cent maximum continuous rating condition then both that condition and the 85 per cent maximum continuous rating condition will form the trial operating conditions. Where unavoidable, any barred range within the values required for the trial operating condition may be excluded on agreement between Owner and Builder subject to approval by LR.

(b) The power absorbed by the propeller(s) is to be that defined in 4.2.4(a). Alternatively, by special agreement, some lesser power could be accepted if it can be demonstrated by the Owner that this would correspond to a more representative normal service condition.

(c) Auxiliary machinery essential for the ship's operating conditions together with HVAC systems are to be running at their normal rated capacity during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary. In addition, the following equipment is to be running if appropriate: stabilisers, waste treatment equipment, swimming pool and jacuzzi equipment.

(d) For sea-going ships, measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship. For other ships, an appropriate water depth is to be agreed with LR prior to the trials.

(e) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code. In addition, noise measurements should not be taken when the wind force exceeds 4 on the Beaufort scale.
(f) The ship is to be at a displacement and trim representative of an operating condition.
(g) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.
(h) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration, are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.
(j) For passenger ships, intermittently run equipment such as transverse propulsion units are to be operated at 60 per cent of their rated power for additional measurements in surrounding ship areas.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:
(a) Measurement locations indicated on a general arrangement of the ship.
(b) The ship's loading condition during survey.
(c) The machinery operating condition, including HVAC system, during survey.
(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO Resolution A.468(XII). Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent Standards are acceptable.

4.3.2 Where the measured noise level exceeds the relevant criterion by 3 dB(A), or contains subjectively annoying low frequency noise or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 When outfitting is complete, and all soft furnishings are in place, sound insulation indices for passenger spaces are to be determined in accordance with ISO 140. Cabin to cabin indices are to be determined from a minimum of three locations within the passenger accommodation, the number of test locations being agreed with LR.

4.3.4 If required, impact sound measurements are to be carried out in accordance with ISO 140/7 and presented in accordance with ISO 717/2. *See* 4.4.4.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that the assessment represents the overall noise environment on board the ship. In addition to the requirements of IMO Resolution A.468(XII) for crew spaces, all public spaces and all passenger spaces are to be measured.

4.4.2 During measurement trials, recognised noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.4.3 In larger sized spaces, where noise levels may vary considerably, such as restaurants, lounges, atria and open deck recreation areas, measurements are to be taken at locations not greater than 7 m apart.

4.4.4 For high speed craft having large passenger saloons, measurements are to be taken along the centreline and along both sides of the saloons at locations not greater than 7 m apart.

4.4.5 The number of and locations for impact noise measurements are to be agreed between the Builder, Owner and LR. The measurements are to be carried out when the ship is in harbour. The number and location of measurements are to take account of all different combinations of construction, areas of application, types of cabin and spaces below.

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 6954:1984 or ISO 6954:2000.

4.5.2 Measurements are to be made with instrumentation meeting the requirements of ISO 8041.

4.5.3 Vibration levels are to be given in terms of the velocity measurement appropriate to the version of the standard being used and should be measured over a period of not less than one minute.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as restaurants, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg, with spikes as appropriate, is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global deck vibrations.

4.7 Approved technical organisation

4.7.1 An approved technical organisation for the purposes of these Rules is one that is acceptable to the Owner and LR with proven capability in noise and vibration measurement and satisfies all the criteria set out below:

(a) Have instrumentation whose calibration, both before and after the measurements, can be traced back to National Standards and, hence, back to International Standards.
(b) Have analysis procedures capable of data reduction to the requirements and standards set out in these Rules.
(c) Be able to provide a written report in English with contents as defined by Section 5.

■ *Section 5* Noise and vibration survey reporting

5.1 General

5.1.1 Prior to survey, a noise and vibration measurement plan is to be agreed by the Owner, Builder and LR.

5.1.2 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.3 The survey report is to be prepared by the organisation undertaking the trial measurements, which may be an approved technical organisation or LR.

5.1.4 The survey report is to be submitted to LR's London Office for evaluation and confirmation that the results are in accordance with the noise and vibration levels specified in these Rules and/or agreed between the Owner and Builder. The assignment of a Class Notation or the issue of a Statement of Compliance will be subject to confirmation by LR.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923, and is to include:

(a) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.
(b) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion by 3 dB(A), or where subjectively annoying low frequency or tonal components were present. The Noise Rating number is also to be given where octave band analyses have been conducted.
(c) Ship and machinery details.
(d) Trial details:
    - Loading condition.
    - Machinery operating condition.
    - Speed.
    - Average water depth under keel.
    - Weather conditions.
    - Sea state.
(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. resolution, averaging time, window function).
(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.
(b) Where ISO 6964:2000 is used, the frequency-weighted overall r.m.s. vibration levels tabulated for all measurement locations calculated using the weighting functions and methodology stated in the standard.
(c) Where ISO 6954:1984 is used, the maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.
(d) Ship and machinery details.
(e) Trial details:
    - Loading condition.
    - Machinery operating condition.
    - Speed.
    - Average water depth under keel.
    - Weather conditions.
    - Sea state.
(f) Frequency analysis parameters (e.g. resolution, averaging time and window function), if the analysis is done in the frequency domain.
(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6* Non periodical survey requirements

6.1 Class notation assignment

6.1.1 Where the assignment of a Class Notation or a Statement of Compliance is requested, an Initial Survey is to comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

6.1.2 The sea trial or initial in-service testing requirements are set out in Section 4, and are to be reported in accordance with Section 5 and evaluated against the requirements of Sections 2 and 3.

6.2 Maintenance of class notation through-life and following modifications

6.2.1 Where an Owner has requested assignment of a Class Notation, arrangements are to be agreed between LR and the Owner to record observations/ complaints of excessive noise and vibration that have been such as to disturb the comfort of passengers and crew. The records of the observations are to be made available to the attending LR Surveyor at each Annual Survey.

6.2.2 Where the observations indicate that the noise and/or vibration levels may exceed the criteria relating to the Class Notation requirements and those measured at the Initial Survey, a measurement programme is to be agreed between the Owner and LR and measurements taken in accordance with these Rules.

6.2.3 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

■ *Section 7* Referenced standards

7.1 Noise

7.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923, *Acoustics – Measurement of noise on board vessels.*
- ISO 717/1, *Acoustics – Rating of sound insulation in buildings and of building elements; Part 1: Airborne sound insulation.*
- ISO 717/2, *Acoustics – Rating of sound insulation in buildings and of building elements: Part 2: Impact sound insulation.*
- IMO Resolution A.468(XII), *Code on noise levels on board ships.*
- *IEC Publication 651, Sound level meters.*
- ISO 140/4, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 4: Field measurements of airborne sound insulation between rooms.*
- ISO 140/7, *Acoustics – Measurement of sound insulation in buildings and of building elements; Part 7: Field measurements of impact sound insulation of floors.*

7.2 Vibration

7.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954:1984, *Mechanical vibration and shock – Guidelines for the overall evaluation of vibration in merchant ships.*
- ISO 6954:2000, *Mechanical vibration and shock – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships.*
- ISO 8041, *Human response to vibration. Measuring instrumentation*.

Rules and Regulations for the Classification of Special Service Craft

Volume 3

Part 4

Additional Requirements for Yachts

July 2012

Lloyd's Register

LIFE MATTERS

Chapter Contents **Part 4**

Contents

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Section 1
Introduction

1.1 General

1.1.1 This Part of the Rules contains the particular requirements for the construction and classification of yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), of 24 m or greater, where these differ from the general Rule requirements indicated in Parts 1 to 17.

1.1.2 The regulations for the construction, classification and Periodical Survey of yachts are given in Part 1.

1.1.3 The minimum requirements in respect of intact stability for yachts are indicated in Pt 1, Ch 2,1.1.

1.1.4 Where a Load Line is to be assigned the yacht is to comply with the appropriate requirements of the National Authority or, in the absence of these, in accordance with the requirements of Chapter 2 and Pt 1, Ch 2,1.1.

1.1.5 The requirements for fire protection detection and extinction are to be in accordance with Part 17.

1.1.6 Yachts over 24 m overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4), may be the subject of National or International regulations concerning construction, safety and manning and compliance with these regulations is the responsibility of the Owners and Builders. Lloyd's Register is able to advise on such matters and to issue applicable certificates where so authorised by the National Authority with which the yacht is registered.

1.1.7 A yacht may take any hull form and method of propulsion described in Parts 1 to 17 of these Rules. Other hull forms or methods of propulsion will be specially considered.

1.1.8 The scantling requirements for yachts constructed from steel, aluminium alloy and composite materials are given in Parts 6, 7 and 8 respectively. Where it is proposed to construct a yacht in wood or other material not specifically covered by the Rules, such proposals will be subject to special consideration on the basis of the Rules.

1.2 Definitions

1.2.1 **Freeboard deck** is as defined in Pt 3, Ch 1,6.3.1. When a lower continuous deck is designated as the freeboard deck, that part of the hull which extends above the freeboard deck is treated as superstructure so far as concerns the application of the conditions of assignment and the calculation of freeboard. It is from this lower continuous deck that the assigned freeboard is calculated.

1.2.2 **Virtual freeboard deck** is an imaginary continuous deck which, if fitted, would enable a freeboard, calculated in accordance with the Load Line requirements, and measured from the virtual freeboard deck, that would result in a draught not less than that corresponding to the assigned freeboard. That part of the enclosed hull which extends above the virtual freeboard deck may be treated as superstructure so far as concerns the application of the conditions of assignment provided it is not less than one standard superstructure height. (*See also* Pt 3, Ch 2,7.2).

Section 2
International Rating Class (IRC) Yachts

2.1 General

2.1.1 The classification of International Rating Class Yachts will be specially considered on the basis of these Rules.

■ *Section 1* General

1.1 Plans and data

1.1.1 Plans and data additional to those required by Pt 3, Ch 1,5 may be required to be submitted for appraisal, subject to the form of the yacht.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

■ *Section 2* Ship side valves

2.1 General

2.1.1 Ship side valves are generally to be in accordance with Pt 15, Ch 2,3, but other materials may be considered.

2.1.2 Valves and sea chests are to be easily accessible and permanently marked. Valves not easily accessible are in addition to be fitted with remote control.

■ *Section 3* Anchor stowage

3.1 General

3.1.1 Where anchors are mounted on stemhead fittings, suitable local sheathing or protection is to be provided in areas where the anchor can make contact with the hull or deck, further precautions are to be taken to minimise hull damage in the event of a collision. The fittings are to be of substantial construction and well secured to the hull and deck.

3.1.2 Details of stemhead fittings incorporating forestay attachments are to be submitted for approval.

■ *Section 4* Bathing and watersport platforms and shell openings

4.1 General

4.1.1 Shell doors including bathing and watersport platforms, are generally to be fitted with a sill not less than 600 mm above the design waterline. All openings are to open into a watertight space with access into the yacht by watertight doors capable of being operated from both sides. The outer shell doors may be of a single or double leaf type with either hand or hand and hydraulic operated door clips to ensure watertightness when at sea. Any locking devices fitted are to 'fail safe' in the event of hydraulic failure. Provision is to be made for doors to be closed and locked by hand in the event of hydraulic failure, *see* Pt 3, Ch 4.

4.1.2 Shell openings with a sill height below, or less than 600 mm above, the design waterline are to be of equivalent structural integrity to the surrounding hull structure. Doors from this space providing internal access are to have a sill height at least 600 mm above the design waterline.

4.1.3 Drainage systems for the above shell openings are to be fitted with non-return valves.

4.1.4 Transom platforms are to be integral with the hull or be separate mechanically secured components.

4.1.5 Integral components are to have scantlings equivalent to the adjacent structure with care taken to ensure continuity of strength with no hard spots.

4.1.6 Separate mechanically secured components are to be of substantial construction and securely fastened to the main structure ensuring bolting and sealing arrangements are satisfactory with no hard spots.

4.1.7 Recesses for passerelles, windlasses, platforms, cockpits, etc., are to be watertight and of equivalent strength to that of the surrounding hull and deck structure with care being taken to ensure continuity of strength. Electrical and hydraulic penetrations (where fitted) are to be through watertight glands. Direct overboard discharges are to be fitted to prevent any accumulation of water in the recess.

■ *Section 5* Deck safety equipment

5.1 General

5.1.1 Sailing yachts are, in general, to be fitted with a pulpit, pushpit and guard wires with hand rails inboard to assist personnel movement around the upper deck. Motor yachts are, in general, to be fitted with bulwarks and/or guard rails.

5.1.2 The size, height and position of bulwarks, pulpit, pushpit and guard rails or wires and the securing points for handrails and lifelines are to be in accordance with National or International Standards, *see also* 6.9. The scantlings and securing arrangements are to be designed to withstand the maximum load that could be exerted upon them in service, details of which are to be indicated in the relevant plans.

5.1.3 Doors fitted in bulwarks are to be of equal strength to the adjacent bulwarks and be capable of being secured closed at sea.

■ *Section 6* Protection of openings

6.1 General

6.1.1 Closing appliances for yachts are, in general, to provide weathertight integrity and safety equivalent to the requirements of Pt 3, Ch 4 taking into consideration reductions depending on the height of the lowest weatherdeck, relative to the design waterline.

6.1.2 The vertical distance between the freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.3 The vertical distance between the virtual freeboard deck and the weatherdeck may be used to reduce the Load Line requirements for closing appliances, coaming heights and openings in the hull, superstructure and deckhouses.

6.1.4 Where this vertical distance (as defined in 6.1.2 and 6.1.3) is at least one standard superstructure height then Load Line requirements for closing appliances, coaming heights and openings apply as if an additional tier of superstructure existed. *See also* Pt 3, Ch 2,7.2.2.

6.1.5 Where this vertical distance (defined in 6.1.2 and 6.1.3) is less than one standard superstructure height the coaming heights of doors, hatches, ventilators, air pipes, etc., may be reduced in proportion to the ratio of the actual distance and one standard superstructure height.

6.2 Hinged weathertight doors

6.2.1 Doors on the weather deck (first tier accommodation) protecting direct access to machinery spaces are to be of substantial construction in accordance with or equivalent to recognised National or International Standards. They are to be permanently attached to the casing, outward opening and gasketed weathertight with a minimum of six clips and have a coaming height of 460 mm with a minimum of 230 mm depending on the excess freeboard.

6.2.2 Doors on the weather deck to first tier accommodation or other spaces protecting access below are to be as required by 6.2.1 with a minimum of four clips. Provided access to the space(s) may be obtained from the deck above, the coaming height may be 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.2.3 Where wood doors are proposed on the weather deck in lieu of doors in 6.2.2 above they are to be strongly constructed of hardwood not less than 50 mm thick, double gasketed with coamings as required by 6.2.2. For doors in exposed locations additional securing arrangements by slip bolts, clamps or equivalent are required. These doors are not to be the sole means of entry or exit from the space. Where these doors may be required to be used as a means of escape in an emergency situation, the additional securing arrangements are to be operable from both sides.

6.2.4 The use of FRP for doors on the weather deck other than to machinery spaces may be accepted, providing the doors are of substantial construction in accordance with 6.2.2.

6.2.5 Proposals to use FRP doors for access to machinery spaces are to comply with 6.2.4 in addition to Part 17, in respect of fire requirements and compliance with any National Authority requirements which may be applicable.

6.2.6 Doors in the second tier accommodation are to be as indicated in 6.2.1 with a minimum of four clips, or wood doors per 6.2.3 and have a coaming height of 100 mm with a minimum of 50 mm depending on the excess freeboard. Sliding doors with equivalent securing arrangements may be accepted.

6.3 Hatches (coamings and covers)

6.3.1 Hatches on the weather deck and deck above are to have a structural integrity of not less than the structure to which they are fitted and are to be weathertight when closed.

6.3.2 Hatches on the weather deck in the forward $0,25L_L$ or to machinery spaces are to be hinged on the forward side and have 460 mm coamings with a minimum of 230 mm depending on the excess freeboard.

6.3.3 Elsewhere on the weather deck, hatches which are proposed to be open at sea and provide access to lower accommodation spaces are to have a coaming height of 230 mm with a minimum of 150 mm depending on the excess freeboard.

6.3.4 Hatches on the deck above the weather deck which are proposed to be open at sea, are to have a coaming height of 150 mm with a minimum of 50 mm depending on the excess freeboard.

6.3.5 Flush hatches that are not closed by gasketed covers and secured by close space bolts will be specially considered but should not, in general, be fitted on the weather deck. However, flush hatches fitted with double gasketed covers with drains led overboard that do not require to be opened at sea and that are in protection locations, will be considered.

6.3.6 Escape hatches are to be operable from both sides.

6.4 Ventilators and air pipes

6.4.1 Ventilators and air pipes are to have coamings complying with Pt 3, Ch 4,11 and Pt 15, Ch 2,11 respectively.

6.4.2 Where necessary for operational reasons, coamings on the weather deck protected by the bulwark, may be reduced to the bulwark height subject to a minimum coaming height of 450 mm for ventilators and 300 mm for air pipes.

6.5 Portlights and windows

6.5.1 The requirements for side scuttles and windows are indicated in Pt 3, Ch 4. Proposals to fit windows below freeboard deck will be specially considered.

6.5.2 Round, elliptical or elongated portlights are to have a structural integrity of not less than the structure to which they are fitted. If fitted below the weatherdeck they are to be provided with permanently attached deadlights. *See also* Pt 3, Ch 4,7.12.2.

6.5.3 Where internal covers are provided, they are to be gasketed and capable of being secured weathertight (with additional backing bars if necessary). Provision is to be made for the storm covers to be stored on board and their stowage location noted in the document ‘For the information of the Master’. Internal storm blinds may be accepted subject to satisfactory tests being carried out.

6.5.4 Chemically toughened glass may be used in lieu of thermally toughened glass provided it can be demonstrated the strength of the arrangement is at least equivalent in strength to that of thermally toughened glass. The glazing system is to be of laminated construction and the method of testing will be specially considered.

6.5.5 Wheelhouse windows are to be of toughened safety glass, or where they are of laminated or sandwich construction, the surface layers are to be of toughened safety glass.

6.5.6 Details of the attachment of windows in their frames and of frames to the yacht structure are to be submitted for approval.

6.5.7 Storm covers or deadlights are required for all windows and portlights in the front of the deckhouse on the weather deck and also the sides, except where these are interchangeable port and starboard; in this case a sufficient number to fit any one side are to be provided. Additionally a storm cover or deadlight is to be provided for each different size of window or portlight respectively.

6.5.8 A glazing equivalent may be fitted in lieu of deadlights or stormcovers on the weather deck and above. The thicknesses and arrangements are to be acceptable to the National Authority with whom the craft is registered and/or by the Administration within whose jurisdiction the ship is intended to operate. For arrangements of glazing acceptable to Lloyd’s Register (hereinafter referred to as LR), *see* Table 2.6.1. Alternative arrangements of glazing in lieu of deadlights or storm covers may be accepted provided details are submitted for consideration.

6.6 Sliding glass doors or glass walls

6.6.1 When sliding glass doors are provided, or a glass wall which includes an access, an alternative access, or exit from the space, is to be provided, and the arrangements are to be in accordance with approved plans and weathertight commensurate with their position. Coaming heights are, in general, to be in accordance with 6.2 and the use of portable coamings will be considered. Details are to be submitted.

6.6.2 The glass used in the above is to be toughened safety glass or equivalent in accordance with 6.5.

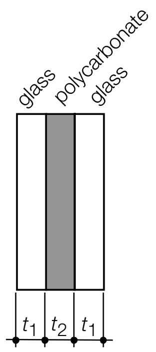
6.6.3 Storm covers of strong construction are to be provided and stored on board. Aft facing glass doors or walls in the second tier and above, are not required to be fitted with storm protection. The use of a virtual freeboard deck to determine storm cover requirements is not permitted. Additional portable supports are to be provided as necessary and full details are to be submitted for approval. Roller shutters or other alternatives will be specially considered.

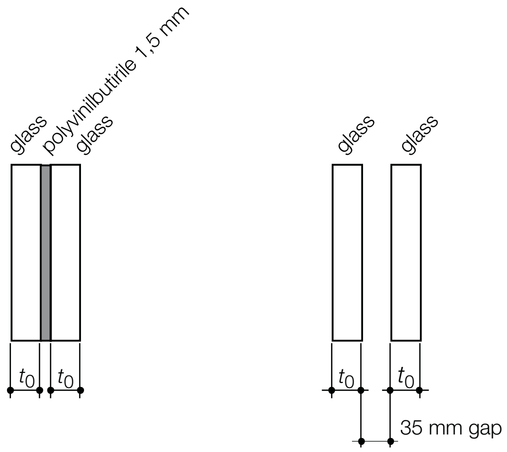
6.6.4 In lieu of a weathertight coaming for the cover, adequate drainage is to be provided between the cover and the glass which may be in the form of a sump drained overboard, with a grating over, details of such proposals should be submitted for individual consideration.

6.7 Scuppers and sanitary discharges

6.7.1 Piping and valves are, in general, to comply with the requirements indicated in Pt 15, Ch 2,3.

Table 2.6.1 Acceptable arrangements of glazing in lieu of portable storm covers/deadlights

<table>
<tr><th>In lieu of portable storm covers</th><th>In lieu of deadlights or storm covers</th></tr>
<tr><td>

$t_1^2 + (0{,}77t_2)^2 + t_1^2 = (1{,}2t_0)^2$</td><td>
</td></tr>
<tr><td colspan="2">Symbols</td></tr>
<tr><td colspan="2">t_0 = minimum thickness of toughened glass as calculated in Pt 3, Ch 4,7.8.1.</td></tr>
</table>

6.8 Freeing ports

6.8.1 In general, freeing ports are to be in accordance with the requirements indicated in Pt 3, Ch 4, taking into consideration the position of the virtual freeboard deck indicated in 6.1.

6.9 Bulwarks, guard rails and wires

6.9.1 Bulwarks, guard rails and wires are in general, to comply with the requirements indicated in Pt 3, Ch 4,8.

6.9.2 Where a bulwark of reduced height is fitted, guard rails or wires are to be provided above the bulwark to a height of 1000 mm above the deck.

6.9.3 Where the proper working of a yacht may otherwise be impeded bulwarks, guard rails of wires of a reduced height may be considered. Details are to be submitted for approval.

6.9.4 Protection is to be provided in way of boats, liferafts, etc.

■ *Section 7*
Corrosion protection

7.1 General

7.1.1 The design of the structure and methods of attachment of fittings are to take into consideration procedures to minimise corrosion of metal structures and fittings due to electro-chemical action. All exposed steel and aluminium alloy surfaces are to be protected by the application of a suitable paint and anti-fouling system and the fitting of a cathodic or impressed current protection system.

7.1.2 Sacrificial anodes are to be mounted equidistant between metals being protected, and their location and attachment is to be such as to obviate hard spots.

7.1.3 Anodes with cast-in galvanised steel straps are to be secured to the steel hull by welded studs or direct welding.

7.1.4 The design and performance characteristics of the cathodic protection system is the Builder's responsibility. Particular attention is to be given to the earth bonding system, to provide good electrical continuity.

7.1.5 Yachts fitted with a negatively grounded electrical system or fitted with a negatively grounded independent battery system may use the impressed current cathodic protection scheme.

7.2 Protection – Aluminium alloy yachts

7.2.1 Anti-fouling paints containing copper are not to be used.

7.2.2 Bilges and internal surfaces subject to salt laden air are to be coated with a waterproof mastic or equivalent.

7.2.3 Particular attention is to be given to the design and selection of materials used for underwater fittings and the associated piping systems to limit the effect of bimetallic corrosion. Where materials other than aluminium are used they are, in general, to be electrically insulated from the hull and internal metal piping or cathodically protected separately by anodes attached directly to such fittings.

7.3 Protection – Composite yachts

7.3.1 Aluminium alloy or steel sterndrives, waterjet units and trim tabs are to be cathodically protected by anodes mounted on the hull, direct to the unit being protected or through the bonding system.

■ *Section 8* Navigation in first-year ice conditions

8.1 General

8.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

8.1.2 Yachts in Service Group G6, which have their own propulsion machinery, and which are built of steel but are not strengthened for navigation in ice, may be eligible for assignment of Finnish-Swedish Ice-Due Class II under the Finnish and Swedish Boards of Navigation *Finnish-Swedish Ice Class Rules*. Yachts in Service Groups G1–G4 inclusive, constructed in any material, together with Yachts in Service Group G6 constructed in aluminium or composites are not eligible for this notation.

■ *Section 9* Support yacht craft

9.1 General

9.1.1 A **support yacht craft** provides support to a 'primary' yacht and may often also be referred to as a 'shadow yacht'. The support yacht may be provided with an extensive range of equipment and facilities to perform these duties, such as small craft, seaplanes, large galleys and waste management systems.

9.1.2 For support yachts, the following are also to be considered according to the load line requirements:
(a) Sill heights of door openings;
(b) Windows and portlights;
(c) Freeing port areas; and
(d) Sill heights of ventilators.

Section

■ *Section 1* Hull design and construction parameters

1.1 Plans and data

1.1.1 In addition to the general plans and data required by Pt 3, Ch 1,5 the following details of additional structural components, particular to sailing yachts, are to be submitted for appraisal:

- Sail plan.
- Mast loadings.
- Bowsprit loadings.
- Rigging loadings.
- Mast step.
- Mast partners.
- Ballast keel lines plan.
- Ballast keel securing arrangements.
- Rudder skeg construction and support details.
- Chainplates.
- Through deck fittings.

1.1.2 All plans are to be presented in a clear and unambiguous manner with sufficient details to avoid misinterpretation.

1.2 Mast and rigging support arrangements

1.2.1 Sailing yacht mast and standing rigging loadings and their support structure require special consideration as follows:

(a) Adequate hull and deck longitudinal structure to resist hull bending.

(b) Provision of adequate transverse structure in way of masts, chainplates, keels, skegs, etc.

(c) Provision of adequate bottom structure to support the mast and dissipate the mast loadings.

(d) Local reinforcement as given in Pt 8, Ch 3,3.14 in way of chainplates, forestay and backstay fittings, etc.

(e) The deck and beams are to be suitably strengthened in way of masts, coachroof/deckhouse ends, windlass, cleats, sheet winches, sheet tracks, etc. Where a mast is stepped on the deck or coachroof/deckhouse the structural arrangements will be specially considered.

1.2.2 Details of the designer's/Builder's calculated maximum loads on the mast heel and the breaking loads of all standing rigging are to be submitted with the main structural plans for appraisal.

1.3 Bowsprits

1.3.1 The hull structure in way of the bowsprit is to be suitably reinforced with due account taken of the compressive loads along the bowsprit and bending moments due to rigging loads.

1.3.2 Details of the designer's/Builder's calculated maximum loads on the bowsprit and the breaking loads of all associated standing rigging are to be submitted with the structural plans for appraisal.

■ *Section 2* Hull construction

2.1 Hull scantlings (composite materials)

2.1.1 The basic structural scantlings are, unless specified within this Section, to be as indicated in Part 8.

2.1.2 The shell weight/thickness determined from Part 8, is to be maintained throughout the length of the craft, with the bottom shell weight extending to the chine line or 150 mm above the static load waterline, whichever is the greater.

2.1.3 The keel plate thickness for sailing yachts is to be 1,1 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of keel to be taken less than the thickness of the adjacent bottom shell or fin and tuck as appropriate.

2.1.4 The fin and tuck thickness is not to be less than 0,9 times the keel thickness for motor craft as determined in Part 8. In no case is the thickness of the fin and tuck to be taken less than the thickness of the adjacent bottom shell.

2.1.5 The construction of hull to deck connections is to be in accordance with Pt 8, Ch 2,5.

2.1.6 The hull laminate is to be strengthened in way of the attachment of chainplates, etc., *see* Pt 8, Ch 2,5.

2.1.7 The stern or transom is to be the same weight as the side shell and is to be adequately stiffened with special consideration being given to the transmission of backstay loadings.

2.1.8 Where twin bilge keels are fitted, the bottom laminate in way of the bilge keels is to be formed by extending the keel reinforcement to a distance not less than 25 per cent the width of the keel, as required by Part 8, outside the line of the outboard edge of the bilge keels or to the supporting structure whichever is the greater, prior to being tapered in accordance with the Rules to the adjacent bottom shell laminate. *See also* 2.1.10.

2.1.9 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets etc. The increase is not to be less than 50 per cent of the adjacent plate laminate. Details of such reinforced areas are to be submitted for consideration.

2.1.10 Local reinforcement is, in general, to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness in accordance with Pt 8, Ch 3,3.14.

2.2 Transversely framed yachts

2.2.1 Sailing yachts with a conventional rig, are to be provided with suitably increased scantlings in floors, frames, beams and brackets adjacent to each mast.

2.2.2 In general, beams at the heads of web frames and four beams in way of each mast in sailing and auxiliary yachts are to have their scantlings increased by a factor of two. Where practicable, masts are to be located in way of transverse bulkheads or other primary stiffening.

2.2.3 Keel mounted masts are to be mounted on a suitable mast step secured to three floors at a height sufficient to provide the necessary structural integrity and to keep the heel of the mast clear of any bilge water.

2.2.4 Keel mounted masts are to be fitted with mast partners running fore and aft on either side of the mast to join the transverse beams. The strength of the mast partners are to be the same as for the beams.

2.2.5 Deck mounted masts are to be housed in a mast step positioned directly over a bulkhead or a web frame/deep beams with a pillar fitted under the mast.

2.3 Longitudinally framed yachts

2.3.1 Conventional masts mounted on mast steps as in 2.2.3 are to be fitted with heavy transverse web frames as required by 2.2.2.

2.4 Yachts fitted with non-conventional rigs

2.4.1 The structure in way of non-conventional mast configurations will be specially considered.

■ *Section 3* Chain plates

3.1 General

3.1.1 Chain plates and other securing arrangements to take the loads of all standing rigging for masts and bowsprits, are to be of substantial construction and well integrated with the hull and/or deck supporting structure. They are to be of sufficient strength that, in the event of failure of the standing rigging, the watertight integrity of the hull is not impaired.

3.1.2 The breaking loads of all mast and bowsprit standing rigging together with the actual loads imposed by the rigging are to be submitted.

3.2 Calculations

3.2.1 The strength of any part of chainplates or structure to which it is attached is not to be less than the breaking load of the rigging to which it is attached and subject to the following factors of safety (FOS).

Items:	Minimum FOS:
Rigging	1,0
Lug, eyebolt eye	1,2
Lug to baseplate	1,2
Eyebolt/base plate to foundation	2,0
Chainplate to foundation (below decks)	2,0
Chainplate foundation to hull structure	2,0

■ *Section 4* Deck planking

4.1 General

4.1.1 The construction of decks of steel, aluminium alloy or composite materials is to be in accordance with Pt 6, Ch 3,8, Pt 7, Ch 3,8 and Pt 8, Ch 3,8 respectively. Wood deck sheathing is in general to be treated as cosmetic and is outside the scope of these Rules. However, any wood sheathing fitted is not to be detrimental to the integrity of the main deck structure. Details of the means of attachment of such wood sheathing are to be submitted for consideration.

4.1.2 Decks constructed of wood will be specially considered on the basis of the Rules.

Section 5 Deck fittings

5.1 General

5.1.1 Due consideration is to be given at the design stage to ensure that additional structural support, by way of pads, brackets etc., is provided in way of deck fittings such as mainsheet and genoa tracks, winches, eyebolts, sail-lead tracks, fairleads, anchor and chain cable handling and securing arrangements, grab rails, guard wires, hatch hinges, etc., which are subject to substantial loadings and or use.

5.1.2 Fittings which are subject to significant loads are, in general, to be through bolted, in single skin areas. The laminate is to be locally increased in thickness as necessary with due account taken of such loadings.

5.1.3 Details of inserts, local reinforcement and through bolting arrangements for yachts of composite construction are to be in accordance with Pt 8, Ch 2 and Ch 3.

Section 6 Ballast keels

6.1 External ballast keel

6.1.1 The ballast keel may be of lead, cast iron or other suitable material. Cast iron or other ferrous metals are not to be used in wood or composite craft sheathed with copper or other non ferrous metal.

6.1.2 Prior to installation the ballast keel is to be 'Dry fitted' to the hull and the top is to be smooth, or slightly concave in all directions, and well coated with a suitable bedding compound.

6.1.3 In composite yachts care is to be taken to prevent crushing of GRP laminates through overtightening of keel bolts.

6.1.4 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not in general exceed 8 mm. The top of the bolt is to have sufficient thread to take double nuts or other suitable locking arrangement. *See also* 6.3.6.

6.1.5 The structure in way of the ballast keel is to be in accordance with the requirements of Parts 6, 7 and 8 for the respective material.

6.1.6 In steel/aluminium alloy yachts all bottom structure in way of the ballast keel(s) is to be welded by means of double continuous welding.

6.1.7 Ballast keels are to be fully supported by floors to distribute the keel loadings to the bottom structure, *see* Pt 8, Ch 3. The scantlings of the floors and frames will be specially considered in conjunction with the keel mass together with the size, material and position of the keel bolts.

6.1.8 Canards and lifting keels are outside the scope of the Rules but the structure in way will be specially considered with regard to maintenance of structural and watertight integrity. Full details are to be submitted for appraisal.

6.2 Internal ballast keel

6.2.1 Where ballast is to be incorporated in the keel, the internal surface is to be suitably coated prior to filling, and on completion the top surface is to be sealed.

6.2.2 For steel and aluminium alloy yachts the method of installing the internal ballast is not to be detrimental to the plating or internal structure. Details of the installation procedure are to be submitted for consideration prior to implementation.

6.2.3 Internal ballast is to be suitably supported and secured against movement. The supporting structure in way of internal ballast is to be suitably increased in strength.

6.2.4 In steel/aluminium yachts, the ballast is to be totally encapsulated by fully welded plating with a minimum thickness of 6 mm. Alternative arrangements will be specially considered.

6.2.5 In composite yachts, the internal ballast is to be encapsulated by a laminate equivalent in thickness to half the rule bottom shell laminate or 2400 g/m^2 CSM (or equivalent), whichever is the greater.

6.3 Keel bolts

6.3.1 The keel bolts are to be of a corrosion resistant material. The nuts, washers, etc., are to be of a material the same as, or compatible with, that of the keel bolts. The specifications of these materials are to be submitted for appraisal.

6.3.2 The diameter of keel bolts, d_k, is to be that determined from the following formula, or 14 mm, whichever is the greater:

$$d_k = 14{,}2 \sqrt{\frac{w\, d_{cg}}{\sigma_u\, b_k}} \text{ mm}$$

where

b_k = breadth of top of ballast keel in way of bolt, in mm

d_{cg} = vertical distance of the centre of gravity of weight, w, below top of ballast keel, in mm

w = the portion of the weight of ballast keel supported by the bolt, in kg

σ_u = ultimate tensile strength of the bolt material, in N/mm^2

When determining w for the bolt at the ends of the keel, the weight of any overhang is to be included.

6.3.3 Where double bolts are to be fitted, the total cross-sectional area of the bolts is to be not less than 1,2 times the cross-sectional area of the bolt determined in accordance with 6.3.2.

6.3.4 Keel bolts are to be fitted alternately on opposite sides of the middle line, and as close as is practicable to the bottom floor structure.

6.3.5 The ballast keel is to be secured by through bolting, but where this is not practicable, short keel bolts or studs may be fitted.

6.3.6 A substantial plate washer is to be fitted under the head of the keel bolt. The diameter and thickness are to be not less than 4,0 and 0,25 times the bolt diameter, respectively, but the thickness need not exceed 8 mm. Washer plates, where square or rectangular, are to have suitably radiused corners. In composite and wood craft the washer plates are to have all edges dressed smooth in addition to being suitably radiused.

6.3.7 The bottoms of short keel bolts are to be secured by nuts and washers fitted in pockets in the keel, or by square plate nuts cast in with the keel. Where cast in, the square plate nuts are to have a breadth and depth not less than 3,0 and 1,0 times the bolt diameter, respectively.

6.3.8 Where studs are fitted, the length of the threaded portion into the cast iron or steel keel is to be not less than 1,5 or 2,5 times the stud diameter where through tapped or blind tapped respectively.

6.3.9 It is recommended that the design of the keel bolt is such that it can be withdrawn for survey and is not cast permanently into the ballast keel.

6.3.10 Details of the proposed torque to be applied to the keel bolts is to be indicated on the relevant plans and submitted.

■ *Section 7* Rudder skegs and rudders

7.1 Skegs

7.1.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

7.1.2 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

7.1.3 The thickness of the skeg plating is in no case to be taken as less than 1,5 times the thickness of the adjacent bottom shell or the fin and tuck laminate whichever is the greater.

7.1.4 Where metallic sub-frames are laminated into skegs, providing transverse stiffening to the skeg and support for the rudder pintle, such stiffening members are to be fully integrated with hull framing to ensure continuity of strength.

7.1.5 The scantlings of skegs of composite construction will be specially considered on the basis of the Rules, and in this respect are to be of equivalent strength and load carrying capability to that required for skegs of steel construction from Pt 3, Ch 3,3. Due account is to be taken of the differing material properties.

7.1.6 Direct calculations may be used as an alternative to the requirements of 7.1.5 to determine the scantlings of composite skegs. Such calculations are to be submitted for appraisal.

7.2 Rudder construction arrangements

7.2.1 Rudder construction for sailing yachts is generally to be in accordance with Pt 3, Ch 3.2.

7.2.2 For use in the determination of the rudder stock diameter, within Table 3.2.7 in Pt 3, Ch 3, the factor f_c may be taken as 70 for yachts with an overall length, L_{OA}, of 24 m varying up to 79 at a length of 50 m. Intermediate values are to be determined by linear interpolation. Yachts with a length, L_R, in excess of 50 m are to comply with Table 3.2.7.

7.2.3 The rudder stock diameter is to be based upon the maximum stated operational speed of the yacht, but in no case is this to be taken less than $2{,}536\sqrt{L_{WL}}$ knots. L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

■ *Section 8* Open cockpits and companionways

8.1 Cockpit construction

8.1.1 Cockpits are to be of watertight construction with scantlings equivalent to that of the upper deck.

8.1.2 Cockpit lockers and hatches where fitted, are to be of substantial construction and are to be tested weathertight.

8.1.3 Where engine removal or other hatches are fitted in the cockpit sole they are to be watertight and bolted down. Detailed plans are to be submitted for approval.

8.1.4 The height of the cockpit sole above the waterline is to be such that the water will effectively drain overboard under all normal conditions of heel and trim.

8.2 Companionways

8.2.1 Companionway openings, are to be sited on, or as close as possible to, the centreline. Sill heights are to be not less than as required by Pt 3, Ch 4.

8.2.2 Companionway hatches are to be of substantial construction capable of being opened from both sides and be tested weathertight.

■ *Section 9* Anchoring and mooring equipment

9.1 General

9.1.1 The requirements of Pt 3, Ch 5 apply to fore and aft rigged sailing yachts of all sizes.

9.1.2 Sailing yachts with three or more masts and fitted with a square rig are to be fitted with anchors 25 per cent heavier than those calculated in accordance with Pt 3, Ch 5. Chain cable, hawsers and warps are to be increased accordingly.

9.1.3 Square rigged yachts are to have a full length of chain cable on the main anchor but may have rope with a chain tail fitted to the second anchor. Kedge anchors may be fitted using the rule length and size of warp without a chain tail.

Rules and Regulations for the Classification of Special Service Craft

Volume 3

Part 5

Design and Load Criteria

July 2012

Lloyd's Register

LIFE MATTERS

Chapter Contents

Contents

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Section 1 Rule application

1.1 General

1.1.1 The global and local load and design criteria detailed in this Part are to be used in conjunction with the formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.2 The global load and design criteria given in this Part are provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation. The strength calculations are, in general, to be conducted using finite element analysis techniques with a three dimensional model.

1.1.3 Load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyd's Register (hereinafter referred to as LR).

1.1.4 Craft built and classed in accordance with the Rules will, in general, be assigned an operational envelope. This will be based on the allowable speeds, significant wave heights and corresponding displacements. It will form an appendix to the Classification Certificate and is to be incorporated in the craft's Operational Manual. The assigned operational envelope is to be clearly displayed in the wheelhouse. Installation of an accelerometer at LCG connected via a visual display in the wheelhouse may be required.

1.1.5 The operational envelope assigned is based on the assumption that the wave height can be visually observed. Where this is not the case, the speed of the craft is to be suitably reduced.

1.1.6 The design assessment is to include a range of speeds covering all modes of operation for which the craft is designed, i.e. speeds corresponding to displacement, semi planing and fully planing. A craft which is designed to operate in the planing mode will need to be assessed using the requirements of Chapter 3 at its design speed and required significant wave height, as well as the requirements of Chapter 4 when operating at reduced speed and a more severe wave height.

1.1.7 The load design criteria given in this Part are dependent on the operating mode of the craft as follows:

- Craft operating in the **non-displacement** mode:
  - Applies to craft operating in full planing or semi-planing modes.
  - Applies to HSC at design speed. HSC is defined in Pt 1, Ch 2,2.2.8.
  - Applies to LDC at design speed. LDC is defined in Pt 1, Ch 2,2.2.10.
  - Applies to craft in foil borne mode.
  - Applies to craft where other lifting devices are actively supporting some or all of the craft's weight.
  - Typically this applies to craft with a Taylor Quotient, Γ, greater than 3. Γ is defined in Ch 2,2.1.18. However, the following is to be noted:
    - Some craft are not designed to plane, but have Γ greater than 3, e.g. SWATHs and fast displacement yachts and, unless they are classified as HSC, then these craft are to be considered as only operating in the displacement mode.
    - Some craft are designed to plane with Γ less than 3 and these should be considered as operating in the non-displacement mode.
- Craft operating in the **displacement** mode:
  - Applies to craft designed to operate in the displacement mode.
  - Applies to all other craft where they are not operating in the non-displacement mode, e.g. at lower speed in severe weather.

Section 2 Direct calculations

2.1 General

2.1.1 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Special Service Craft Software

2.2.1 LR's direct calculation procedures and facilities are summarised in a publication entitled the LR *Software Guide*.

2.3 Submission of direct calculations

2.3.1 In cases where direct calculations have been carried out using procedures available in the LR *Software Guide* the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the model.

(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.3.2 In general, all input data and output results are required to be submitted. In such cases, magnetic media with agreed format may be used for submission.

2.3.3 The responsibility for error free specification and input of program data and the subsequent correct transposal of output rests with the designer/Builder.

■ *Section 3* Model experiments

3.1 General

3.1.1 Model experiments and theoretical calculations may be required to be carried out for new design concepts and the results are to be provided when plans are submitted for approval.

3.1.2 Where model testing is undertaken, the following details are to be submitted:
(a) A summary of the model construction and its instrumentation, including calibration of instruments.
(b) A summary of the testing arrangements and procedures.
(c) A summary of the tank facilities and test equipment.
(d) Details of the wave generation, response measurements, definitions and notations.
(e) Details of data recording, reduction and data analysis procedures.
(f) Details of calibration procedures with theoretical computations.
(g) Tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in Table 1.3.1 is required to be carried out.

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas
Heading	Beam, head, stern and quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave frequency	Six frequencies

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data are to be obtained where practicable:
(a) Vertical accelerations at the LCG, bow and stern.
(b) Acceleration loads due to heave and pitch.
(c) Vertical bending moment.
(d) Bow impact pressures at full forward speed.
(e) Oblique sea loads inducing dynamic torque on the cross structure for multi-hull craft.
(f) Splitting loads due to beam seas and roll motion for multi-hull craft.
(g) Impact pressures in tunnel side and top for multi-hull craft.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval.

3.2.4 Results from open water model experiments and full scale measurements may be accepted and full details are to be submitted for appraisal.

Section

Section 1
Environmental conditions

1.1 General

1.1.1 This Chapter contains information regarding the derivation of load criteria which are to be used for the computation of local design criteria in Chapters 3 and 4.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents from which design data are to be derived.

1.1.3 These environmental conditions are usually described by physical variables of statistical nature.

1.1.4 The load criteria used for design are to be based on environmental data for the specific area and operation of the craft.

1.1.5 The loads imposed by the environment are to be based on extreme conditions. These arise as the craft advances in a seaway and is loaded and stressed in a random manner by dynamic forces and moments.

1.1.6 The load criteria given here are derived from experimental and theoretical studies complemented with service experience.

1.1.7 Alternative methods of establishing the load criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

Section 2
Definitions and symbols

2.1 Parameters to be used for the determination of load and design criteria

2.1.1 **Air gap.** The air gap, G_A, is the minimum vertical distance, in metres, from the static waterline to the point considered in an operational condition. In no case is G_A to be taken greater then $G_{A(max)}$ as indicated in Fig. 2.2.1.

2.1.2 **Allowable speed *V*.** The allowable speed used in the computation of environmental loads is the design speed, in knots, associated with a nominated operational environment in which the craft is certified at corresponding operational displacement.

2.1.3 **Beaufort Number.** Beaufort Number is a measure of wind strength.

2.1.4 **Bilge tangential point.** For craft with partially submerged hull(s), the bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see* Fig. 2.2.2. For craft with fully submerged hull(s), the bilge tangential point is defined as the intersection points between the hull and the design waterline.

2.1.5 **Deadrise angle.** For craft with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal of the line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see* Fig. 2.2.2. For craft with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used. For craft with fully submerged hull with circular sections, the deadrise angle is to be taken as 30°.

2.1.6 **Displacement mode.** Displacement mode means the regime, whether at rest or in motion, where the weight of the craft is fully or predominantly supported by hydrostatic forces.

2.1.7 **Froude Number F_n.** The Froude Number is a non-dimensional speed parameter and is defined as:

$$F_n = \frac{0{,}515 V_m}{\sqrt{g\, L_{WL}}}$$

where
g is the acceleration due to gravity and is taken to be 9,81 m/s^2.
L_{WL} is defined in 2.1.19.
V_m is the appropriate speed in knots.

2.1.8 **LCG.** The LCG is the longitudinal centre of gravity of the craft in the loading condition under consideration.

2.1.9 **Maximum wave height.** In general the maximum wave height, in metres, will be taken as 1,667 times the significant wave height. Where, for design purposes, a wave length is required this will be taken as the waterline length subject to any restriction resulting from limiting height to length ratio and wave profile angle.

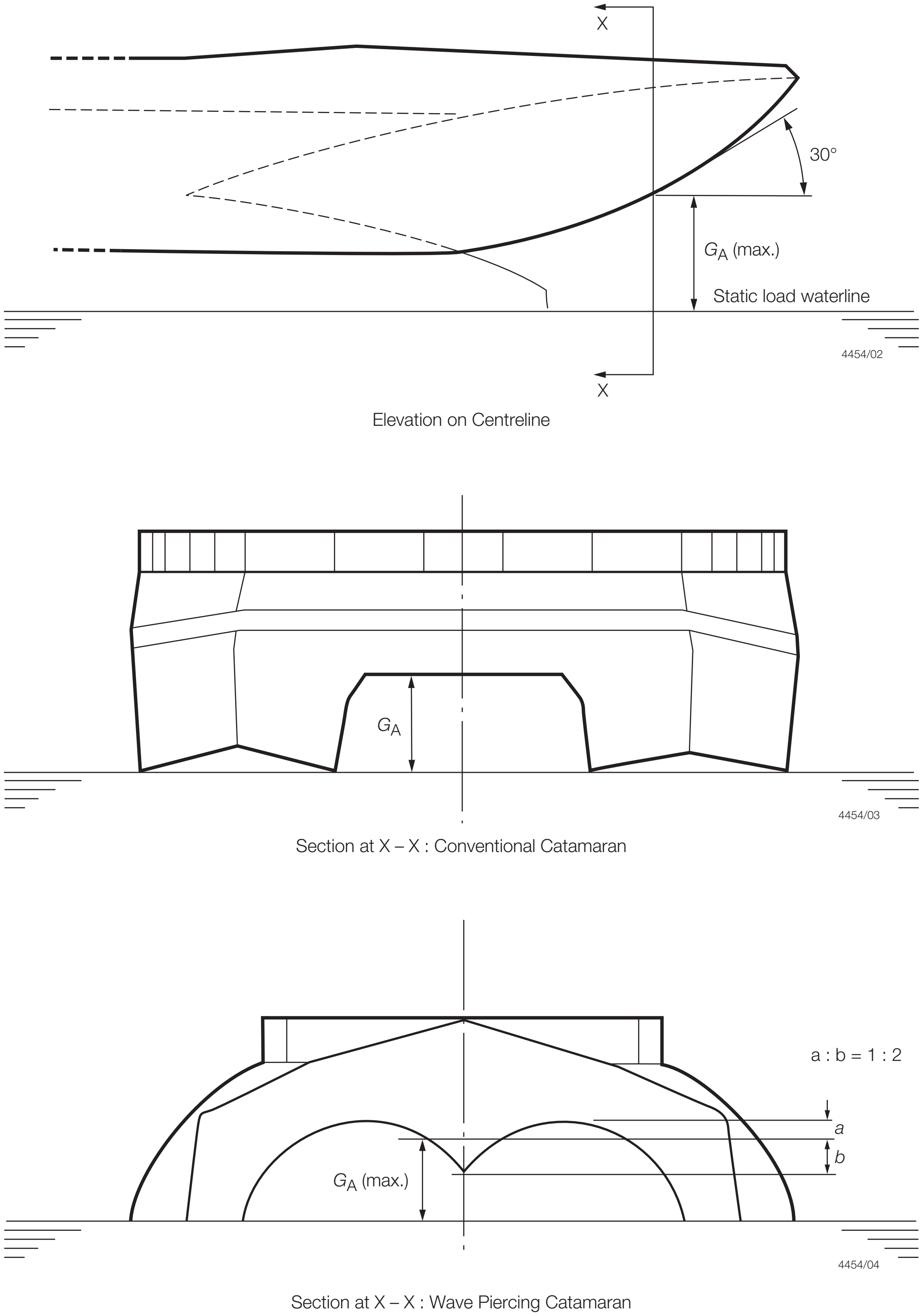


Fig. 2.2.1 Definition of air gap

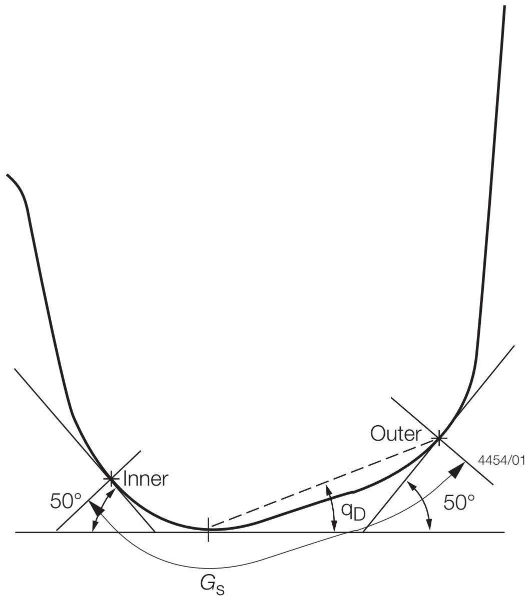


Fig. 2.2.2
Definition of bilge tangential point and G_s for craft with partially submerged hulls

2.1.10 **Non-displacement mode.** Non-displacement mode means the normal operational regime of a craft when non-hydrostatic forces substantially or predominantly support the weight of the craft.

2.1.11 **Operating waterline** is the waterline for the operating condition under consideration.

2.1.12 **Period.** The period is defined as the average time interval between upward crossings of the mean value.

2.1.13 **Sea state.** Sea state is an expression used to categorise wave conditions and is normally defined by sea spectrum, significant wave height and period distribution.

2.1.14 **Significant wave height $H_{1/3}$.** The wave height, in metres, used in the determination of craft motions and loads is a significant wave height, $H_{1/3}$, defined as the average of the one third highest waves in a short term wave measurement record.

2.1.15 **Support girth.** The support girth, G_s, is the girth distance, in metres, measured around the circumference of the shell plate between the tangential points or chines, as appropriate, of the hull for a mono-hull craft. For multi-hull craft it is to be taken between the inner and outer bilge tangential points or chines of the individual hulls. *See* 2.1.4 and Fig. 2.2.2.

2.1.16 **Surviving wave height H_{03}.** The wave height, in metres, used in the determination of the structural integrity of a craft and is defined as the wave height with three per cent probability of exceedance. If this value is unknown, the following equation is to be used to determine H_{03}:

$$H_{03} = 1{,}29 H_{1/3}$$

2.1.17 **Taylor Quotient Γ.** The Taylor Quotient is defined as:

$$\Gamma = \frac{V}{\sqrt{L_{WL}}}$$

where V is defined in 2.1.2 and L_{WL} is defined in 2.1.19.

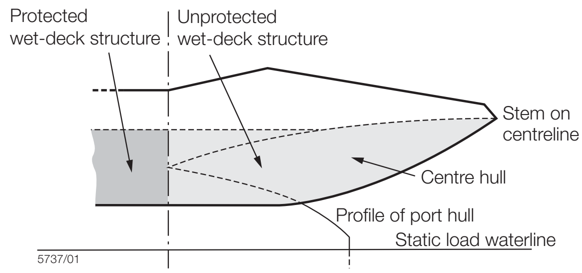
2.1.18 **Volumetric speed number F_v.** The Volumetric speed number is defined as:

$$F_v = 7{,}19\,\nabla^{1/6}$$

where ∇ is the moulded displacement, in m^3, of the craft corresponding to the design waterline.

2.1.19 **Waterline length.** Waterline length, L_{WL}, is as defined in Pt 3, Ch 1,6.2.

2.1.20 **Protected structure,** *see* Fig. 2.2.3. A protected structure is one in which the wet-deck component under consideration is enclosed by port and starboard side inboard structure, where ‘side inboard’ is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.



Elevation on centreline: Wave-piercing catamaran

Fig. 2.2.3
Definition of wet-deck protected and unprotected structure

2.1.21 **Unprotected structure,** *see* Fig. 2.2.3. An unprotected structure is one in which the wet-deck component under consideration is not enclosed by port and starboard side inboard structure, where ‘side inboard’ is as defined in Ch 4,1.5.6 of Parts 6, 7 and 8 for craft of steel, aluminium alloy and composite construction respectively.

2.2 Symbols

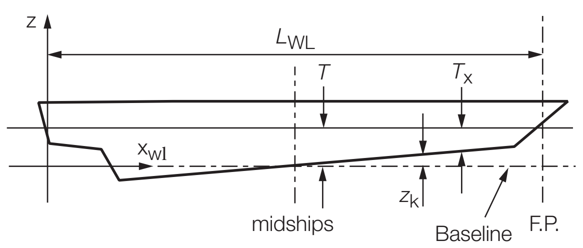
2.2.1 L_R, B, D, C_b, L_{WL} and T are as defined in Pt 3, Ch 1,6.2:

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

z = vertical distance, in metres, from the baseline to the position of centre of gravity of the item being considered. z is positive above the baseline
Normally the following definitions are to be applied:
z is to be taken at one third of the panel or strake height
For short stiffener members: z is to be taken at the stiffener mid position
For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see* Fig. 2.2.4

T_x = local draught to operating waterline at longitudinal position under consideration measured above the baseline is to be taken as the horizontal plane passing through the bottom of the moulded hull at midships, *see* Fig. 2.2.4.



NOTE
For any position $T = z_k + T_x$

Fig. 2.2.4 Definition of Symbols

2.2.2 The displacement, Δ, in tonnes, used in this Part is the mass of the craft in the loading condition under consideration.

2.3 Minimum significant wave height

2.3.1 The minimum value of significant wave height, $H_{1/3}$, *see* 2.1.14, in metres, used in the determination of accelerations and loads is, in general, not to be taken less than that given in Table 2.2.1 for the appropriate Service Groups defined in Pt 1, Ch 2,3.5.

2.3.2 The designer/Builder is to provide the value of significant wave height for use in the determination of the Rule loadings and, further, is to ensure that such a wave height is appropriate to the intended area of operation and/or service. In this respect the statistical wave data may be required to be submitted in support of the wave height nominated.

Table 2.2.1 Minimum significant wave height, $H_{1/3}$

Service Group	Minimum significant wave height, in metres
1	0,6
2	1,0
2A	1,5
3	2,0
4	4,0
5	4,0
6	4,0

2.3.3 A reduction in the minimum value of significant wave height for a particular Service Group will be specially considered, provided that satisfactory statistical wave data for the intended service area are submitted for approval. *See also* 2.1.14.

Section 3
Motion response

3.1 Relative vertical motion

3.1.1 The relative vertical motion is to be taken as:

$$H_{rm} = C_{w,min}\left(1 + \frac{k_r}{(C_b + 0{,}2)}\left(\frac{x_{wl}}{L_{WL}} - x_m\right)^2\right)$$

where

k_r = *see* Table 2.3.1

$$C_{w,min} = \frac{C_w}{k_m}$$

$$k_m = 1 + \frac{k_r\,(0{,}5 - x_m)^2}{(C_b + 0{,}2)}$$

x_m = $0{,}45 - 0{,}6F_n$ but not less than 0,2

C_w = wave head, in metres
= $0{,}0771 L_{WL}\,(C_b + 0{,}2)^{0,3}\ e^{(-0{,}0044 L_{WL})}$

x_{wl} = distance from aft end of L_{WL}, in metres, *see* 2.2.1

L_{WL} = waterline length, in metres, *see* 2.1.19

C_b = block coefficient, *see* 2.2

F_n = Froude Number, *see* 2.1.7, where $V_m = {}^{2}/_{3}V$

V as defined in 2.1.2.

Table 2.3.1 Hull form wave pressure factor

Craft type	k_r
Mono-hull craft in the non-displacement mode	2,25
Mono-hull craft in the displacement mode	1,95
Catamarans and multi-hull craft with partially submerged hulls	2,55
Swaths and multi-hull craft with fully submerged hulls	2,10
Craft supported by hydrodynamic lift provided by foils or other lifting devices	1,50
NOTE Where multiple craft types apply, the higher value of k_r is to be used.	

3.2 Vertical acceleration

3.2.1 The instantaneous accelerations determined in accordance with the formulae in this Section are to be used to estimate the relationship between allowable speed, V, in knots, wave height, $H_{1/3}$, in metres, and displacement, Δ, in tonnes, and they will form the operational envelope which will be issued as an appendix to the Classification Certificate and be incorporated in the Operational Manual of the craft where such a manual is required by the Rules.

3.2.2 Where the Taylor Quotient, Γ, is greater than 10,8, the motion response criteria are to be specially considered.

3.2.3 The vertical acceleration at the LCG (longitudinal centre of gravity), a_v, is defined as the average of the 1/100 highest accelerations at the LCG.

3.2.4 The vertical acceleration in the non-displacement mode for mono-hull craft is to be taken as:

$$a_v = 1{,}5\theta_B L_1 (H_1 + 0{,}084)(5 - 0{,}1\theta_D)\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g
g = acceleration due to gravity (9,81 m/sec^2)
$H_1 = \dfrac{H_{1/3}}{B_W}$, but is not to be taken as less than 0,2
$H_{1/3}$ = design significant wave height in metres
B_c = breadth of hull between the chines or bilge tangential points at LCG, as appropriate, in metres
B_W = breadth of hull at the LCG measured at the waterline, in metres
$L_1 = \dfrac{L_{WL} B_c^3}{B_W \Delta}$, but $\dfrac{L_{WL}}{B_W}$ is not to be taken as less than 3
L_{WL} = waterline length, in metres, *see* 2.1.19
θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°
θ_B = running trim angle in degrees, but is not to be taken as less than 3°
Γ = Taylor Quotient, *see* 2.1.17
Δ = displacement, in tonnes, as defined in 2.2.2.

3.2.5 The vertical acceleration in the non-displacement mode for multi-hull craft is to be taken as:

$$a_v = \frac{f_a L_{WL}}{\Delta}(B_M H_{1/3} + 0{,}084 B_M^2)(5 - 0{,}1\theta_D)\Gamma^2 \times 10^{-3}$$

where

a_v is the vertical acceleration at the LCG in terms of g
f_a = hull form acceleration factor
= 2,7 for craft supported mainly by hydrodynamic lift provided by foils or other lifting devices
= 3,6 for Swaths and multi-hull craft with fully submerged hulls
= 4,5 for catamarans and multi-hull craft with partially submerged hulls
B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels
$H_{1/3}$ = design significant wave height, in metres
L_{WL} = waterline length, in metres, *see* 2.1.19
θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°, *see* 2.1.5
Γ = Taylor Quotient, *see* 2.1.17
Δ = displacement, in tonnes.

3.2.6 The vertical acceleration in the displacement mode for all craft is to be taken as:

$$a_v = 0{,}2\Gamma + \frac{34}{L_{WL}}$$

where

a_v is the vertical acceleration at the LCG in terms of g
L_{WL} = waterline length, in metres, *see* 2.1.19
Γ = Taylor Quotient, *see* 2.1.17.

3.2.7 The vertical acceleration, a_x, at any given location distance x_a from the AP along the hull may be taken as:

$$a_x = a_v\left(0{,}86 - 0{,}32\frac{x_a}{L_{WL}} + 1{,}76\left(\frac{x_a}{L_{WL}}\right)^2 + \xi_a\right)$$

where

a_v = vertical acceleration at LCG in terms of g, as appropriate
a_x = is the vertical acceleration at a distance x_a from AP on the static load waterline, in terms of g
x_a = distance from aft end of the static load waterline, in metres, to the point at which the vertical acceleration is calculated
x_{LCG} = distance from aft end of the static load waterline, in metres, to the LCG
L_{WL} = waterline length, in metres, *see* 2.1.19
$\xi_a = 0{,}14 + 0{,}32\dfrac{x_{LCG}}{L_{WL}} - 1{,}76\left(\dfrac{x_{LCG}}{L_{WL}}\right)^2$

■ *Section 4*
Loads on shell envelope

4.1 Pressures on the shell envelope

4.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition, the effects of impact or slamming loads are also to be considered, but these are to be treated separately, *see* Section 5.

4.1.2 The individual pressure components are given in 4.3 to 4.5 and the combined pressure to be applied to the shell envelope is given in 4.2. The pressure to be applied to exposed and weather decks is given in 4.5.

4.2 Combined hydrostatic and hydrodynamic pressure on the shell plating

4.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in Fig. 2.4.1 and is to be taken as specified in Table 2.4.1.

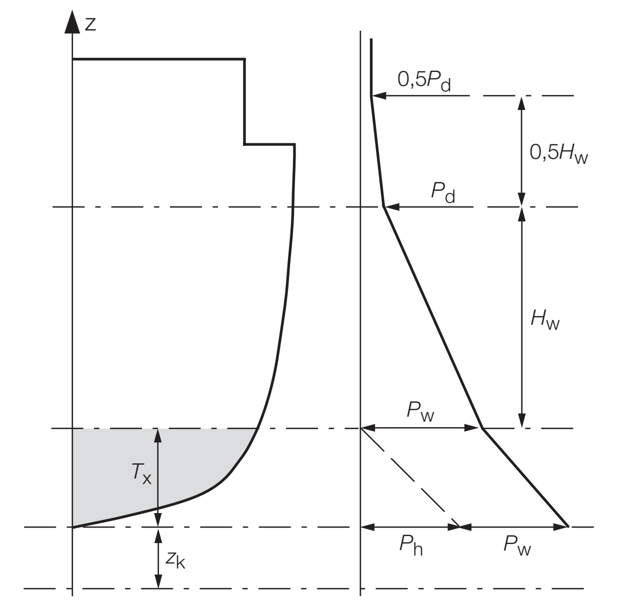


Fig. 2.4.1 Combined pressure distribution, P_s

Table 2.4.1 Combined pressure distribution, P_s

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
For $z \le T_x + z_k$ i.e. up to the operating waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \ge T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	
H_w is the nominal wave limit height, *see* 4.4.4 P_d is the weather deck pressure, *see* 4.5.1 P_h is the hydrostatic pressure, *see* 4.3 P_w is the hydrodynamic wave pressure, *see* 4.4 P_h and P_w are to be derived at the appropriate vertical position, z T_x, z and z_k are defined in 2.2	
NOTE Pressure values at other z values are to be derived by interpolation.	

4.3 Hydrostatic pressure on the shell plating

4.3.1 The pressure, P_h, acting on the shell plating up to the operating waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10\,(T_x - (z - z_k)) \text{ kN/m}^2$$

where
T_x, z and z_k are defined in 2.2.

4.4 Hydrodynamic wave pressure

4.4.1 The hydrodynamic wave pressure distribution due to relative motion, P_w, around the shell envelope up to the operating waterline, i.e. $z \le T$, is to be taken as the greater of the following:

P_m kN/m^2 as defined in 4.4.2
P_p kN/m^2 as defined in 4.4.3.

4.4.2 The distribution of hydrodynamic pressure up to the operating waterline, P_m, is to be taken as:

$$P_m = 10 f_z H_{rm} \text{ kN/m}^2$$

where

f_z = the vertical distribution factor

$$= k_z + (1 - k_z)\left(\frac{z - z_k}{T_x}\right)$$

$$k_z = e^{-u}$$

$$u = \left(\frac{2\pi\,T_x}{L_{WL}}\right)$$

H_{rm} is defined in 3.1.1
z, z_k, T_x and L_{WL} are defined in 2.2.

4.4.3 The distribution of hydrodynamic pressure up to the operating waterline, P_p, is to be taken as:

$$P_p = 10 H_{pm} \text{ kN/m}^2$$

where

$$H_{pm} = 1{,}1\left(\frac{2x_{wl}}{L_{WL}} - 1\right)\sqrt{L_{WL}}$$

but not less than $f_L \sqrt{L_{WL}}$

f_L = 0,6 for $L_{WL} < 60$
= $1{,}5 - 0{,}015 L_{WL}$ for $60 \le L_{WL} \le 80$
= 0,3 for $L_{WL} > 80$
L_{WL} = as defined in 2.1.19, but not greater than 150 m
x_{wl} is defined in 3.1.

4.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2H_{rm} \text{ m}$$

where
H_{rm} is given in 3.1.1.

4.5 Pressure on weather and interior decks

4.5.1 The pressure acting on weather decks, P_d, is to be taken as specified in 4.5.2 or 4.5.3 as applicable.

4.5.2 The pressure acting on weather and interior decks, P_{wh}, in the displacement mode is to be taken as:

$$P_{wh} = f_L (6 + 0{,}01 L_{WL}) (1 + 0{,}05\,\Gamma) + E \quad \text{kN/m}^2$$

where

f_L = the location factor for weather decks
= 1,0 from aft end to $0{,}88L_R$
= 1,25 from $0{,}88L_R$ to $0{,}925L_R$
= 1,50 from $0{,}925L_R$ to forward end

f_L = 1,0 for interior decks

$E = \dfrac{0{,}7 + 0{,}08L_{WL}}{D - T}$ kN/m^2 for exposed decks but need not be taken greater than 3 kN/m^2

E = 0,0 for sheltered decks

Γ = Taylor Quotient as defined in 2.1.17

Δ = the displacement as defined in 2.2

L_{WL} is as defined in 2.1.19.

4.5.3 The pressure acting on weather and interior decks, P_{wl}, in the non-displacement mode is to be taken as:

$$P_{wl} = f_L (5 + 0{,}01 L_{WL}) (1 + 0{,}5a_v) + E \quad \text{kN/m}^2$$

where f_L and E are as defined in 4.5.2, and a_v is as defined in Section 3.

- a_v is not to be taken less than 1,0, but need not be taken greater than 4,0, for weather decks.
- a_v need not be taken greater than 1,0 for interior decks.

L_{WL} is as defined in 2.1.19.

■ *Section 5* Impact loads

5.1 Impact pressure for displacement mode

5.1.1 The impact pressure, P_{dh}, for mono-hull and multi-hull craft is to be taken as specified in 5.1.2 and 5.1.3 as applicable.

5.1.2 The bottom shell impact pressure due to bottom slamming is given by the following expression:

$$P_{dh} = \Phi_{dh}\left(19 - 2720\left(\frac{T_x}{L_{WL}}\right)^2\right)\sqrt{L_{WL}\,V} \quad \text{kN/m}^2$$

$P_{dh} \geq P_m$

Φ_{dh} = 0,09 at L_{WL} from aft end of L_{WL}
= 0,18 at $0{,}9L_{WL}$ from aft end of L_{WL}
= 0,18 at $0{,}8L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}5L_{WL}$ from aft end of L_{WL}

L_{WL} = waterline length, in metres, *see* 2.1.19

V = allowable speed in knots, *see* 2.1.2.

Intermediate values to be determined by linear interpolation.
T_x is taken to be the draught T, as defined in Pt 3, Ch 1,6, but need not be taken greater than $0{,}08L_{WL}$.
P_{dh} at $0{,}9L_{WL}$ and $0{,}8L_{WL}$ from aft end of L_{WL} need not be taken greater than P_f at L_{WL} from aft end of L_{WL} as defined in 5.4.1.

5.1.3 The side shell impact pressure shall be taken as P_{dh} at the operating waterline, reducing to $0{,}4P_{dh}$ at the weather deck. Intermediate values between the weather deck at side and operating waterline, are to be determined by linear interpolation.

5.2 Impact pressure for non-displacement mode

5.2.1 The impact pressure, P_{dl}, for mono-hull and multi-hull craft is to be taken as specified in 5.2.2 and 5.2.3 as applicable.

5.2.2 The bottom impact pressure due to slamming, P_{dlb}, is given by the following expression:

$$P_{dlb} = \frac{f_d\,\Delta\,\Phi\,(1 + a_v)}{L_{WL}\,G_o} \quad \text{kN/m}^2$$

where

G_o = support girth or girth distance, in metres, as defined in Table 2.5.1

L_{WL} = waterline length, in metres, *see* 2.1.19

a_v = vertical acceleration as defined in 3.2

Δ = displacement, in tonnes, *see* 2.2.2

f_d = hull form pressure factor
= 54 for mono-hull craft
$= \dfrac{81}{N_H}$ for catamarans and multi-hull craft, where

N_H is the number of hulls, but it is not to be taken as greater than four

For craft in continuous contact with water:

Φ = 0,5 at L_{WL} from aft end of L_{WL}
= 1,0 at $0{,}75L_{WL}$ from aft end of L_{WL}
= 1,0 at $0{,}5L_{WL}$ from aft end of L_{WL}
= 0,5 at aft end of L_{WL}

Intermediate values to be determined by linear interpolation.
Otherwise, Φ = 1,0.

Table 2.5.1 Definition of G_o for the determination of bottom impact pressure, P_{dl}, for different regions of the hull

Bottom shell region	G_o	
	Craft with chines	Craft without chines
Between tangential points or chines	G_S	G_S
Between tangential points and design waterline	—	G_{WL}

NOTES
1. G_S = support girth, in metres, as defined in 2.1.15 at LCG.
2. G_{WL} = girth distance, in metres, measured between the waterlines on either side of a hull at the LCG.

5.2.3 The side shell impact pressure due to slamming is to be taken as:

$$P_{\text{dls}} = P_{\text{dlb}} \frac{\tan(40 - \theta_B)}{\tan(\theta_S - 40)} \text{ kN/m}^2\text{, but is not to be taken}$$

as greater than P_{dlb}

where

θ_B = mean deadrise angle of bottom plating, in degrees at local section

θ_S = mean deadrise angle of side plating, in degrees at local section

$(40 - \theta_B)$ is not to be taken as less than 10 degrees

$(\theta_S - 40)$ is not to be taken as less than 10 degrees

P_{dls} is to be taken as constant from the chine or operating waterline to a point half G_o from this point, or the weather deck if this is reached first. Multiple chines will be subject to special consideration based on the above principle. *See* Fig. 2.5.1.

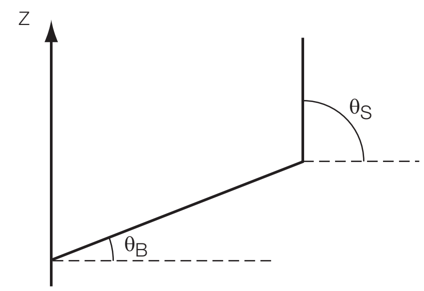


Fig. 2.5.1
Angles used in determination of side shell pressure for planing craft, P_{dls}

5.3 Impact pressure for craft with foils and lifting devices

5.3.1 The impact pressure, P_{fb}, for craft supported by hydrodynamic lift provided by foils or other lifting devices is to be taken as specified in 5.3.2 and 5.3.3, as applicable.

5.3.2 The bottom impact pressure is given by the greater of P_{fba} or P_{fbb}, where:

$$P_{\text{fba}} = \frac{16}{L_{\text{WL}}} \left(H_{03} + \sqrt{H_0 L_{\text{WL}}} \right)^2 \text{ kN/m}^2$$

$$P_{\text{fbb}} = \frac{1}{3} K_{\text{po}} V_R V \left(1 - \frac{H_0}{H_{03}} \right) \text{ kN/m}^2$$

where

K_{po} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0{,}75L_{\text{WL}}$
= 2,0 at L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation

H_0 = operational height of craft, in metres, measured from the waterline to the top of the keel at LCG

L_{WL} = waterline length, in metres, *see* 2.1.19

H_{03} = surviving waveheight as defined in 2.1.15 but is not taken as less than 1,0

V = allowable speed, in knots, *see* 2.1.2

P_{fbb} is not taken as less than zero.

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{\text{WL}}}} + 2 \text{ knots.}$$

5.3.3 The side shell impact pressure shall be taken as P_{fb} at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}3P_{\text{fb}}$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.4 Forebody impact pressure for displacement mode

5.4.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

$P_f = f_f L_{\text{WL}} (0{,}8 + 0{,}15\Gamma)^2$ kN/m^2 at FP

$P_f = P_{\text{dh}}$ at $0{,}9L_{\text{WL}}$ from aft end of L_{WL}
= P_m at $0{,}75L_{\text{WL}}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}75L_{\text{WL}}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation

where

f_f = forebody impact pressure factor as defined in Table 2.5.2

L_{WL} = waterline length, in metres, *see* 2.1.19

Γ = Taylor Quotient, *see* 2.1.17.

Table 2.5.2 Forebody impact pressure factor

Craft type	f_f
Mono-hull craft in non-displacement mode	0,94
Mono-hull craft in displacement mode	0,89
Catamarans and multi-hull craft with partially submerged hulls	1,0
Swaths and multi-hull craft with fully submerged hulls	0,91
Craft supported by hydrodynamic lift provided by foils or other lifting devices	0,81
NOTE Where multiple craft types apply, the higher value of f_f is to be used.	

5.4.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}4P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpolation.

5.5 Forebody impact pressure for non-displacement mode

5.5.1 Forebody and bow slamming pressure, P_f, at the load waterline due to relative motion is to be taken as:

P_f = the greater of P_{dls} or $f_f L_{WL}$ $(0{,}8 + 0{,}15\Gamma)^2$ kN/m^2 at FP
= P_{dls} at $0{,}75L_{WL}$ from aft end of L_{WL}
= P_m at $0{,}5L_{WL}$ from aft end of L_{WL}
= 0,0 between aft end of L_{WL} and $0{,}5L_{WL}$ from aft end of L_{WL}

Intermediate values to be determined by linear interpolation.

where

f_f = forebody impact pressure factor as defined in Table 2.5.2
L_{WL} = waterline length, in metres, *see* 2.1.19
Γ = Taylor Quotient, *see* 2.1.17.

5.5.2 The side shell impact pressure shall be taken as P_f at the chine or at the operating waterline for round bilge hull-forms, as appropriate, reducing to $0{,}3P_f$ at the weather deck. Intermediate values between the weather deck at side and the chine or operating waterline, as appropriate, are to be determined by linear interpretation.

Section 6
Cross-deck structure for multi-hull craft

6.1 Cross-deck structure clearance

6.1.1 For craft with multi-hulls linked by cross-deck structure, sufficient clearance is to be provided between the cross-deck structure and water surface to limit impact loads.

6.1.2 Where part or all of the cross-deck is intended to provide additional buoyancy to limit craft motion, the loading will be specially considered.

6.1.3 In the determination of the clearance, the following factors are to be considered:

(a) Relative motion in waves.
(b) The wave generated between the hulls when running.
(c) The bow sinkage.

6.1.4 The submitted clearance must be validated either by calculations according to accepted theories, model tests, full scale measurements or by documentary evidence if similar structures have proved to be satisfactory in service.

6.1.5 Where it is not possible to provide sufficient clearance to avoid slamming of the cross-deck structure, the equation given in 6.2 is to be used for the assessment of the impact pressures.

6.2 Impact pressure

6.2.1 The impact pressure, P_{pc}, acting on the underside of the cross deck ('wet deck') is to be taken as:

$$P_{pc} = \nabla_{pc} K_{pc} V_R V \left(1 - \frac{G_A}{H_{03}}\right) \text{ kN/m}^2$$

where

K_{pc} = longitudinal distribution factor
= 1,0 between the aft end of the L_{WL} and $0{,}75L_{WL}$
= 2,0 at the L_{WL} from the aft end of L_{WL}, intermediate values to be determined by linear interpolation
G_A = air gap, as defined in 2.1.1
H_{03} = surviving waveheight, as defined in 2.1.16
V = allowable speed, as defined in 2.1.2
∇_{pc} = cross-deck Impact Factor
= 1/6 for protected structures, as defined in 2.1.20
= 1/3 for unprotected structures, as defined in 2.1.21

V_R is the relative vertical speed of the craft at impact, in knots. If this value is unknown, then the following equation is to be used:

$$V_R = \frac{8H_{1/3}}{\sqrt{L_{WL}}} + 2 \text{ knots.}$$

Section 7
Component design loads

7.1 Deckhouses, bulwarks and superstructures

7.1.1 The design pressure, P_{dhp}, for the plating of deck-houses, bulwarks and first tier and above superstructures is given by:

$$P_{dhp} = C_1 P_d \text{ kN/m}^2$$

For structures other than windows:

C_1 = 1,25 for deckhouse and superstructure fronts on upper deck within the forward third of L_R
= 1,15 for deckhouse and superstructure fronts on upper deck outside the forward third of L_R and exposed machinery casings on the upper deck
= 1,0 for deckhouse and superstructure fronts above the lowest tier
= 0,8 for superstructure sides. A value of 0,64 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,5 elsewhere
L_R = Rule length in metres, *see* 2.2.1

For windows of toughened safety glass:

$$C_1 = W_1 W_2 W_3$$

In no case is the design pressure for windows of toughened safety glass to be taken less than $P_{dhp,min}$ as given by:

$$P_{dhp,min} = W_1 G_f S_f (10 + 0{,}04L_{WL}) \text{ kN/m}^2$$

where

x_b = distance, in metres, from AP
y = vertical distance, in metres, from the static load waterline at the deepest design draught to the structural element considered
F = $(D - T)$ in metres

L_{WL} = waterline length, in metres, *see* 2.1.19.
W_1 = 2,0 for the lowest tier of unprotected front
= 1,5 for superstructure fronts above the lowest tier
= 1,0 for superstructure sides. A value of 0,8 may be used where the sides of the superstructure are stepped in from the sides of the craft by 1,0 m or more
= 0,67 elsewhere
W_2 = 0,67 + 0,33 (x_b/L_{WL}) where $x_b > 0,5L_{WL}$ from AP
= 0,67 elsewhere
W_3 = $1 - (y - F)/y$
G_f and S_f are defined in Chapter 3 or Chapter 4 as appropriate.
P_d is defined in 4.5.
D and *T* are as defined in Pt 3, Ch 1,6.2.

7.2 Watertight and deep tank bulkheads

7.2.1 The design pressure, P_{bh}, on watertight and deep tank bulkheads is to be taken as:

P_{bh} = $11,2h_b$ kN/m^2 for deep tank bulkheads
= $7,2h_b$ kN/m^2 for watertight bulkheads

where
h_b = load head in metres, measured vertically as follows:

(a) Watertight bulkheads
- (i) Plating: the distance from a point one-third of the height of the plate above its lower edge to the bulkhead deck at side.
- (ii) Stiffeners: the distance from mid-point of stiffener span to the bulkhead deck at side.

(b) Deep tank bulkheads
For determination of head, the overflow is to be taken as not less than 1,8 m above the crown of the tank.
- (i) Plating: the greater of:
  - the distance from a point one-third of the height of the plate above its lower edge to the top of the tank
  - half the distance from a point one third of the height of the plate above its lower edge to the top of the overflow.
- (ii) Stiffeners: the greater of:
  - the distance from mid-point of span to the top of the tank
  - half the distance from mid point of span to the top of the overflow.

7.3 Pillars

7.3.1 The design load, P_{PI}, supported by a pillar is to be taken as:

P_{PI} = $S_{gt}\, b_{gt}\, P_c + P_a$ kN

where
b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres
P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over
P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2
S_{gt} = spacing, or mean spacing, of girders or transverses, in metres
P_{PI} is not to be taken less than 5 kN.

7.4 Deck area designed for cargo, stores and equipment

7.4.1 The cargo deck design pressure, P_{cd}, for plating is to be taken as:

P_{cd} = $W_{CDP}(1 + 0,5a_x)$ kN/m^2

where a_x is given in Ch 2,3.1.7 and is not to be taken as less than 1,0.
W_{CDP} is the pressure exerted by the cargo on deck specified by the designer in kN/m^2.

■ *Section 1* General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to craft when operating in the non-displacement mode, *see* Ch 1,1.1.

1.1.2 Planing and semi-planing craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, greater than or equal to 3,0.

1.1.3 Light displacement craft are craft with displacement, Δ, in tonnes, less than or equal to $0{,}04(L_R\, B)^{1{,}5}$, as defined in Pt 1, Ch 2,2.2.10.

1.1.4 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft respectively as defined in Part 1.

1.1.5 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dl} = impact pressure, *see* Ch 2,5.2
P_{fb} = impact pressure for craft supported by hydrodynamic lift provided by foils or other lifting devices, *see* Ch 2,5.3
P_s = shell envelope pressure, *see* Ch 2,4.2
P_f = forebody impact pressure, *see* Ch 2,5.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wl} = pressure on weather deck, *see* Ch 2,4.5
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{WDP} = design pressure for weather deck plating
P_{WDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating
Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Craft type notation assigned as defined in Pt 1, Ch 2,3.7.
(e) Type of stiffening members.

2.2.2 In general, the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

Design pressure = $\delta_f\, H_f\, G_f\, S_f\, C_f$ x load criterion

where
C_f = craft type notation factor given in Table 3.2.4
G_f = service area restriction notation factor given in Table 3.2.2
H_f = hull notation factor given in Table 3.2.1
S_f = service type factor notation given in Table 3.2.3
δ_f = stiffening type factor as given in Table 3.2.5.

Table 3.2.1 Hull notation factor, H_f

Hull notation	Factor
HSC **LDC**	1,0 0,95
NOTE For a craft eligible for both **HSC** and **LDC** notation, the higher value is to be used. H_f is to be taken as 1,0 for a craft not eligible for either the **HSC** or the **LDC** notation.	

Table 3.2.2 Service area notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G2A	0,8
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 3.2.3 Service type notation factor, S_f

Service type notation	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 3.2.4 Craft type notation factor, C_f

Craft type notation	Factor
Catamaran	1,0
Hydrofoil	1,1
Mono	1,0
Multi	1,1
RIB	1,15
SES	1,0
SWATH	1,0

Table 3.2.5 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

Section 3
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 3.3.1.

Table 3.3.1 Design pressures for non-displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f\ S_f\ P_s$ $H_f\ S_f\ C_f\ P_{dl}$ $H_f\ S_f\ G_f\ C_f\ P_f$		P_{BF}	Greater of $\delta_f\ H_f\ S_f\ P_s$ $\delta_f\ H_f\ S_f\ C_f\ P_{dl}$ $\delta_f\ H_f\ S_f\ G_f\ C_f\ P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f\ S_f\ P_s$ $H_f\ S_f\ C_f\ P_{fb}$		P_{BF}	Greater of $\delta_f\ H_f\ S_f\ P_s$ $\delta_f\ H_f\ S_f\ C_f\ P_{fb}$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\ P_{BP}$	
Multi-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f\ S_f\ P_s$ $H_f\ S_f\ C_f\ P_{dl}$ $H_f\ S_f\ G_f\ C_f\ P_f$		P_{BF}	Greater of $\delta_f\ H_f\ S_f\ P_s$ $\delta_f\ H_f\ S_f\ C_f\ P_{dl}$ $\delta_f\ H_f\ S_f\ G_f\ C_f\ P_f$	
	Craft with foils or other lifting devices	P_{BP}	Greater of $H_f\ S_f\ P_s$ $H_f\ S_f\ C_f\ P_{fb}$		P_{BF}	Greater of $\delta_f\ H_f\ S_f\ P_s$ $\delta_f\ H_f\ S_f\ C_f\ P_{fb}$	
	Fully submerged hulls	P_{BP}	Greater of $H_f\ S_f\ P_s$ $H_f\ S_f\ G_f\ P_f$		P_{BF}	Greater of $\delta_f\ H_f\ S_f\ P_s$ $\delta_f\ H_f\ S_f\ G_f\ P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\ P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} $1{,}6\ P_{WDP}$ at wet deck		P_{SF}	Greater of $\delta_f\ P_{BP}$ $1{,}9\ P_{WDP}$ at wet deck	
Wet deck		P_{CP}	Greater of $H_f\ S_f\ P_p$ $H_f\ S_f\ P_{pc}$		P_{CF}	Greater of $\delta_f\ H_f\ S_f\ P_p$ $\delta_f\ H_f\ S_f\ P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f\ S_f\ G_f\ C_f\ P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f\ H_f\ S_f\ G_f\ C_f\ P_{wl}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f\ S_f\ G_f\ C_f\ P_{wl}$	7	P_{CRF}	$\delta_f\ H_f\ S_f\ G_f\ C_f\ P_{wl}$	7
Interior deck		P_{IDP}	Greater of $H_f\ S_f\ C_f\ P_{wl}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f\ H_f\ S_f\ C_f\ P_{wl}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f\ S_f\ G_f\ C_f\ P_{dhp}$		P_{DHF}	$\delta_f\ H_f\ S_f\ G_f\ C_f\ P_{dhp}$	
Inner bottom		P_{IBP}	$H_f\ S_f\ P_m + P_h$	$10T$	P_{IBF}	$\delta_f\ (H_f\ S_f\ P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

Local Design Criteria for Craft Operating in Displacement Mode

Section

■ *Section 1* General

1.1 Application

1.1.1 The design criteria given in this Chapter are applicable to all craft when operating in the displacement mode.

1.1.2 Displacement craft are craft with Taylor's Quotient, Γ, as defined in Ch 2,2.1.17, less than 3,0 and with displacement, Δ, in tonnes, greater than $0{,}04(L_R\ B)^{1{,}5}$, as defined in Ch 2,2.2.2.

1.1.3 The design criteria detailed in this Chapter are to be used in conjunction with the load criteria given in Chapter 2 together with the strength formulae given in Parts 6, 7 and 8 to determine the scantlings of steel, aluminium alloy and composite craft as defined in Part 1.

1.1.4 Alternative methods of establishing the design criteria will be specially considered, provided that they are based on established Codes or Standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter is given below:

P_p = pitching pressure, *see* Ch 2,4.4
P_{dh} = impact pressure, *see* Ch 2,5.1
P_{dhp} = deckhouse, bulwarks and superstructure pressure, *see* Ch 2,7.1
P_s = shell envelope pressure, *see* Ch 2,4.1
P_f = forebody impact pressure, *see* Ch 2,5.4
P_{pc} = impact pressure acting on the cross-deck structure, *see* Ch 2,6.2
P_{wh} = pressure on weather deck, *see* Ch 2,4.5
P_{cd} = cargo deck pressure, *see* Ch 2,7.4
P_{bh} = watertight and deep tank bulkhead pressure, *see* Ch 2,7.2
P_{BP} = design pressure for bottom plating
P_{BF} = design pressure for bottom stiffening
P_h = hydrostatic pressure, *see* Ch 2,4.3
P_{SP} = design pressure for side shell plating
P_{SF} = design pressure for side shell stiffening
P_{CP} = design pressure for cross-deck plating
P_{CF} = design pressure for cross-deck stiffening
P_{WDP} = design pressure for weather deck plating
P_{WCDF} = design pressure for weather deck stiffening
P_{CRP} = design pressure for coachroof plating
P_{CRF} = design pressure for coachroof stiffening
P_{IDP} = design pressure for interior deck plating
P_{IDF} = design pressure for interior deck stiffening
P_{IBP} = design pressure for inner bottom plating
P_{IBF} = design pressure for inner bottom stiffening
P_{DHP} = design pressure for deckhouse, bulwarks and superstructures plating and windows
P_{DHF} = design pressure for deckhouse, bulwarks and superstructure stiffening
P_{BHP} = design pressure for bulkheads
P_{CDP} = design pressure for cargo deck plating
Δ and Γ are defined in Ch 2,2.2.2 and Ch 2,2.1.17
T, L_R and B are as defined in Pt 3, Ch 1,6.2.

2.1.2 The unit for pressure is kN/m^2.

2.1.3 The design pressure, P, used in the scantling formulae given in Parts 3, 6, 7 and 8 is to be taken as equal to the appropriate value as defined in this Chapter.

2.2 Design factors

2.2.1 The design pressures on structural components are to be calculated taking into consideration the following factors:

(a) Hull notation assigned as defined in Pt 1, Ch 2,3.4.
(b) Service area restriction notation assigned as defined in Pt 1, Ch 2,3.5.
(c) Service type notation assigned as defined in Pt 1, Ch 2,3.6.
(d) Type of stiffening members.

2.2.2 In general the design pressure, in kN/m^2, for a particular structural component is to be determined as follows:

$$\text{Design pressure} = \delta_f H_f G_f S_f \text{ x load criterion}$$

where

G_f = service area restriction notation factor given in Table 4.2.1
H_f = 1,05
S_f = service type factor notation given in Table 4.2.2
δ_f = stiffening type factor as given in Table 4.2.3.

Table 4.2.1 Service area restriction notation factor, G_f

Service area restriction notation	Factor
G1	0,6
G2	0,75
G2A	0,8
G3	0,85
G4	1,0
G5	1,2
G6	1,25

Table 4.2.2 Service type notation factor, S_f

Service type notation factor	Factor
Cargo (A)	1,0
Cargo (B)	1,1
Passenger	1,0
Passenger (A)	1,0
Passenger (B)	1,1
Patrol	1,2
Pilot	1,25
Yacht	1,1
Workboat	1,25

Table 4.2.3 Stiffening type factor, δ_f

Type	δ_f
Primary stiffening members and transverse frames	0,5
Secondary and local stiffening members Transverse beams	0,8

■ *Section 3*
Hull envelope design criteria

3.1 Hull structures

3.1.1 The design pressures, in kN/m^2, to be used to determine the scantlings of structural elements are to be taken as specified in Table 4.3.1.

Table 4.3.1 Design pressures for displacement craft

Category/location	Craft type	Symbol	Plating pressure	Min.	Symbol	Stiffener pressure	Min.
Mono-hull craft							
Bottom shell	Basic craft	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, G_f\, P_{dh}$ $H_f\, S_f\, G_f\, P_f$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, G_f\, P_{dh}$ $\delta_f\, H_f\, S_f\, G_f\, P_f$	
Side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\, P_{BP}$	
Multi-hull craft							
Bottom shell	Partially submerged hulls	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, G_f\, P_{dh}$ $H_f\, S_f\, G_f\, P_f$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, G_f\, P_{dh}$ $\delta_f\, H_f\, S_f\, G_f\, P_f$	
	Fully submerged hulls	P_{BP}	Greater of $H_f\, S_f\, P_s$ $H_f\, S_f\, G_f\, P_f$		P_{BF}	Greater of $\delta_f\, H_f\, S_f\, P_s$ $\delta_f\, H_f\, S_f\, G_f\, P_f$	
Outboard side shell		P_{SP}	P_{BP}		P_{SF}	$\delta_f\, P_{BP}$	
Inboard side shell		P_{SP}	Greater of P_{BP} 1,6 P_{WDP} at wet deck		P_{SF}	Greater of $\delta_f\, P_{BP}$ 1,9 P_{WDP} at wet deck	
Wet deck		P_{CP}	Greater of $H_f\, S_f\, P_p$ $H_f\, S_f\, P_{pc}$		P_{CF}	Greater of $\delta_f\, H_f\, S_f\, P_p$ $\delta_f\, H_f\, S_f\, P_{pc}$	
Components							
Weather deck *see* Note 1		P_{WDP}	Greater of $H_f\, S_f\, G_f\, P_{wl}$ P_{cd}	7	P_{WDF}	Greater of $\delta_f\, H_f\, S_f\, G_f\, P_{wh}$ P_{cd}	7
Coachroof, *see* Note 1		P_{CRP}	$H_f\, S_f\, G_f\, P_{wl}$	7	P_{CRF}	$\delta_f\, H_f\, S_f\, G_f\, P_{wh}$	7
Interior deck		P_{IDP}	Greater of $H_f\, S_f\, P_{wh}$ P_{cd}	3,5	P_{IDF}	Greater of $\delta_f\, H_f\, S_f\, P_{wh}$ P_{cd}	3,5
Deckhouses, bulwarks and superstructure		P_{DHP}	$H_f\, S_f\, G_f\, P_{dhp}$		P_{DHF}	$\delta_f\, H_f\, S_f\, G_f\, P_{dhp}$	
Inner bottom		P_{IBP}	$H_f\, S_f\, P_m + P_h$	$10T$	P_{IBF}	$\delta_f\, (H_f\, S_f\, P_m + P_h)$	$10T$
Watertight and deep tank bulkheads		P_{BHP}	P_{bh}		P_{BHF}	P_{bh}	

NOTES
1. G_f is not to be taken less than 1,0.
2. The result of each row in each cell is found as the product of all items on that row in that cell.

Section 1 General

1.1 Introduction

1.1.1 The global load and design criteria detailed in this Chapter are to be used in conjunction with Parts 6, 7 and 8 to determine the global hull strength requirements for steel, aluminium alloys and composite craft respectively as defined in Pt 1, Ch 2,2.1.1.

1.1.2 The global load and design criteria given in this Chapter are also provided to enable the designer/Builder to check global hull strength against ductile failure modes involving gross deformation.

1.1.3 The global load criteria are divided into two categories:

(a) Hull girder loads
The types of hull girder loads which are to be considered for strength purposes are distinguished on the basis of their frequencies and they are defined as follows:
  (i) Still water bending moments and associated shear forces arising from mass distribution and buoyancy forces.
  (ii) Vertical wave bending moments and associated shear forces arising from low frequency hydrodynamic forces.
  (iii) Dynamic bending moments and associated shear forces arising from high frequency bottom slamming.

(b) Primary loads for multi-hull craft
These loads arise from the interaction between the hulls and waves.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.1.5 Longitudinal strength calculations are to be carried out and submitted for approval for craft as required in Parts 6, 7 and 8, as appropriate, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. The calculations of still water shear forces and bending moments are to cover both departure and arrival conditions and any special mid-voyage conditions caused by changes in ballast distribution.

1.1.6 L_R, B, D, T and C_b are as defined in Pt 3, Ch 1,6.

1.1.7 The vertical acceleration at the LCG, a_v, in terms of g, as defined in Ch 2,3.2, as appropriate, is not to be taken less than 1,0 for the purpose of determining the global load and design criteria.

Section 2 Hull girder load criteria for mono-hull craft

2.1 General

2.1.1 The vertical bending moments specified here are applicable to all mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.2 Vertical wave bending moments

2.2.1 For all craft except patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W at any position along the craft may be taken as follows:

$M_W = F_f\, D_f\, M_o$ kNm

where

F_f = –1,1 for sagging (negative) moment
= $1{,}9C_b/(C_b + 0{,}7)$ for hogging (positive) moment

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between $0{,}4L_R$ and $0{,}65L_R$
= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1L_f\, G_f\, L_R^2\, B\, (C_b + 0{,}7)$ kNm

$L_f = 0{,}0412L_R + 4{,}0$, for $L_R < 90$ m
$= 10{,}75 - (3 - 0{,}01L_R)^{1{,}5}$, for $L_R \geq 90$ m

G_f = Service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,65 for G2A craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft (yachts only)

L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

C_b to be taken not less than 0,60.

2.2.2 For patrol craft in Service Group G6, the minimum value of vertical wave bending moment, M_W, at any position along the ship may be taken as follows:

$M_W = F_f D_f M_o$ kNm

where

F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the craft above the waterline. F_{fS} is the sagging (negative) moment correction factor and is to be taken as:

$F_{fS} = -1{,}10 R_A^{0,3}$ for values of $R_A \geq 1{,}0$

$F_{fS} = -1{,}10$ for values of $R_A < 1{,}0$

R_A is an area ratio factor, *see* 2.2.3

An area ratio value of 1,0 results in a sagging correction factor of –1,10

F_{fH} is the hogging (positive) moment correction factor and is to be taken as

$F_{fH} \equiv 1{,}9C_b/(C_b + 0{,}7)$

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between $0{,}4L_R$ and $0{,}65L_R$
= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

$M_o = 0{,}1 L_f L_R^2 B_{WL} (C_b + 0{,}7)$ kNm

$L_f = 0{,}0412L_R + 4{,}0$, for $L_R < 90$ m
$= 10{,}75 - (3 - 0{,}01L_R)^{1,5}$, for $L_R \geq 90$ m

B_{WL} = maximum breadth at the design waterline, in metres

C_b to be taken not less than 0,60.

2.2.3 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_A = \frac{30\,(A_{BF} + 0{,}5A_{SF})}{L_R\, B_{WL}}$$

where

A_{BF} is the bow flare area, in m², *see* 2.2.4

A_{SF} is the stern flare area, in m², *see* 2.2.5.

2.2.4 The bow flare area, A_{BF}, is illustrated in Fig. 5.2.1 and may be derived as follows:

$A_{BF} = A_{UB} - A_{LB}$ m²

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of $0{,}8L_R$ from the AP.

A_{LB} = half the water plane area at the design waterline of the bow region of the hull forward of $0{,}8L_R$ from the AP.

Note the AP is to be taken at the aft end of the Rule length, L_R

The design waterline is to be taken at T, *see* Pt 3, Ch 1.

Alternatively the following formula may be used:

$A_{BF} = 0{,}05L_R (b_0 + 2b_1 + b_2) + b_0\, a/2$ m²

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design waterline at the FP, in metres, *see* Fig. 5.2.1

b_1 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}9L_R$ from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design waterline at $0{,}8L_R$ from the AP, in metres

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ is a waterline taken $L_f/2$ m above the design waterline

$T_{C,U} = T + L_f/2$ m

L_f is given in 2.2.2.

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

2.2.5 The stern flare area, A_{SF}, is illustrated in Fig. 5.2.1 and is to be derived as follows:

$A_{SF} = A_{US} - A_{LS}$ m²

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to $0{,}2L_R$ forward of the AP

$T_{C,L}$ is a waterline taken $L_f/2$ m below the design waterline

$T_{C,L} = T - L_f/2$ m

L_f is given in 2.2.2.

For craft with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

2.2.6 The sagging correction factor, F_{fS}, in the vertical wave bending moment formulation in 2.2.2 may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

2.3 Still water bending moments

2.3.1 The still water bending moment, M_S, hogging and sagging is the maximum moment calculated from the loading conditions.

2.3.2 Still water bending moments are to be calculated along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of L_R. Hogging bending moments are positive.

2.4 Wave shear force

2.4.1 The wave shear force, Q_W, at any position along the craft is given by:

$$Q_W = \frac{3K_f\, M_o}{L_R} \text{ kN}$$

where K_f is to be taken as follows:

(a) Positive shear force:

K_f = 0 at aft end of L_R
= $1{,}589C_b/(C_b + 0{,}7)$ between $0{,}2L_R$ and $0{,}3L_R$ from aft end of L_R
= 0,7 between $0{,}4L_R$ and $0{,}6L_R$ from aft end of L_R
= 1,0 between $0{,}7L_R$ and $0{,}85L_R$ from aft end of L_R
= 0 at forward end of L_R

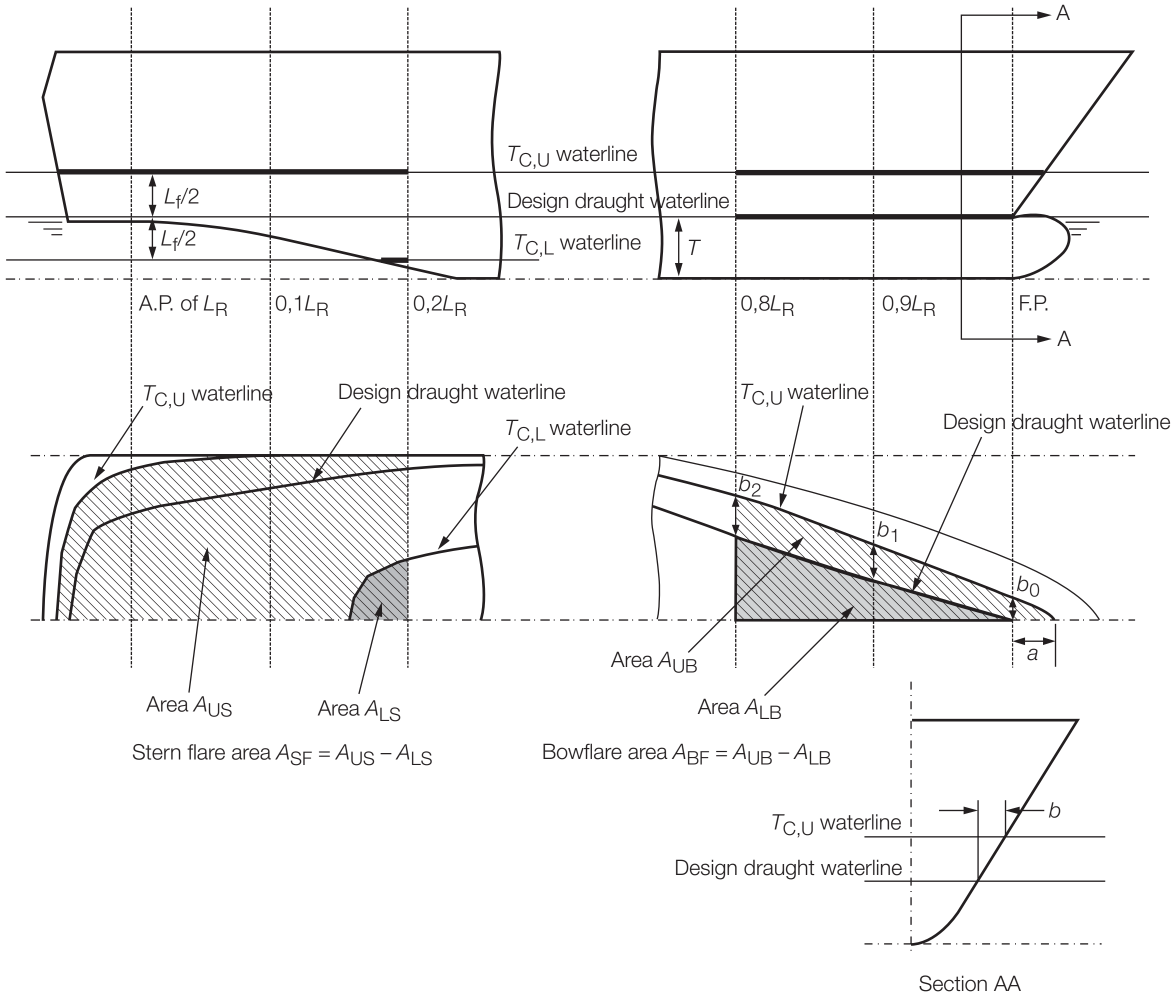


Fig. 5.2.1 Derivation of bow and stern flare areas

(b) Negative shear force:

K_f = 0 at aft end of L_R
= –0,92 between 0,2L_R and 0,3L_R from aft end of L_R
= –0,7 between 0,4L_R and 0,6L_R from aft end of L_R
= –1,727C_b/(C_b + 0,7) between 0,7L_R and 0,85L_R from aft end of L_R
= 0 at forward end of L_R

Intermediate values to be determined by linear interpolation.
M_o, C_b are as defined in 2.2.1 and 2.2.2.

2.5 Still water shear force

2.5.1 The still water shear force, Q_s, at each transverse section along the hull is to be taken as the maximum positive and negative value found from the longitudinal strength calculations.

2.5.2 Still water shear forces are to be calculated at each section along the craft length. For these calculations, downward loads are to be taken as positive values and are to be integrated in a forward direction from the aft end of L_R. The shear force is positive when the algebraic sum of all vertical forces aft of the section is positive.

2.5.3 The actual shear force obtained from the longitudinal strength calculations may be corrected for the effect of local forces at the transverse bulkhead, if applicable.

2.6 Dynamic bending moments and associated shear forces

2.6.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement mono-hull craft as defined in Pt 1, Ch 2,2.2.12.

2.6.2 The dynamic bending moment, due to slamming effects at amidships, is to be calculated using the following expression:

$M_{DW} = F_f D_f |M_D|$ kNm

where

$|M_D|$ is taken to be the absolute value of the function, irrespective of signs
M_D = $51\Delta L_R (16a_v - 4a_b - 17a_s - 5) 10^{-3}$ kNm
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment
D_f = 0 at aft end of L_R

= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R
a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.4, *see also* 1.1.6
a_b = vertical acceleration at forward end of L_R, in terms of g
a_s = vertical acceleration at aft end of L_R, in terms of g

If the values of a_b and a_s are unknown, the distributions given in Ch 2,3.2.7 are applicable.

2.6.3 The bottom longitudinal amidships are additionally subjected to the following effective pressure, P_s:

$P_s = 0{,}14P_{dl} + 8T$ kN/m^2

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$P_t = 0{,}175P_{dl} + 10T$ kN/m^2

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

2.6.5 The dynamic shear force, Q_{DW}, at any position along the craft is given by:

$$Q_{DW} = \frac{4K_f\,M_D}{L_R} \quad \text{kN}$$

where M_D is as defined in 2.6.2 and K_f is as defined in 2.4.1.

■ *Section 3* Hull girder load criteria for multi-hull craft

3.1 General

3.1.1 The vertical bending moments specified here are applicable to all multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.1.2 L_R and T are as defined in Pt 3, Ch 1,6.

3.2 Vertical wave bending moments and associated shear forces

3.2.1 The vertical wave bending moments, M_{MW}, including wave and still water effects, at amidship is given by the following:

$M_{MW} = F_f\,D_f\,M_M$ kNm

where

$M_M = S_f\,G_f\,E_f\,C_{WP}\,L_S^{2,5}\,B_M$ kNm
C_{WP} = the waterplane area coefficient and is to be taken not less than 0,5
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,5 for G1 craft
= 0,6 for G2 craft
= 0,65 for G2A craft
= 0,7 for G3 craft
= 0,8 for G4 craft
= 1,0 for G5 and G6 craft
S_f = 1,1 for passenger and cargo craft
= 1,15 for craft other than cargo and passenger craft
E_f = 0,125 for sagging moment
= 0,2 for hogging moment
F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment
D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft end of L_R
= 0 at forward end of L_R
B_M = total breadth of hulls or struts at LCG at the waterline, in metres, excluding tunnels
L_S = Rule length, L_R, in metres, for partially submerged hulls
= strut length, in metres, for fully submerged hulls.

3.2.2 The wave shear force, Q_{MW}, at any position along the craft is given by:

$$Q_{MW} = \frac{3K_f\,M_M}{L_S} \quad \text{kN}$$

where M_M is as defined in 3.2.1 and K_f is as defined in 2.4.1.

3.3 Dynamic bending moments

3.3.1 The dynamic bending moments, including wave and still water effects, specified here are applicable to all non-displacement multi-hull craft as defined in Pt 1, Ch 2,2.2.13.

3.3.2 The dynamic bending moment, M_{MDW}, due to slamming effects at amidships is to be calculated using the following expression:

$M_{MDW} = F_f\,D_f\,M_{MD}$ kNm

where

$M_{MD} = 52\Delta\,L_S\,(20\,a_v - 5) \times 10^{-3}$ kNm
F_f = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment
D_f = 0 at aft end of L_R
= 1,0 between $0,4L_R$ and $0,65L_R$ from aft
= 0 at forward end of L_R
a_v = vertical acceleration at the LCG, in terms of g, as defined in Ch 2,3.2.5 as appropriate, *see also* 1.1.6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

L_S is as defined in 3.2.1.

3.3.3 The bottom longitudinals amidships are additionally subjected to the following effective pressure, P_s:

$P_s = 0{,}14P_{dl} + 8T$ kN/m^2

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

3.3.4 The bottom plating amidships is subjected to the following additional effective pressure, P_t:

$P_t = 0{,}175P_{dl} + 10T$ kN/m^2

where

P_{dl} is as defined in Ch 2,5.2.1. T is as defined in Pt 3, Ch 1,6.

3.3.5 The dynamic shear force, Q_{MDW}, at any position along the craft is given by:

$$Q_{MDW} = \frac{4K_f M_{MD}}{L_S} \text{ kN}$$

where M_{MD} is as defined in 3.3.2. and K_f as defined in 2.4.1.

Section 4
Primary load criteria for multi-hull craft

4.1 General

4.1.1 For multi-hull craft, the strength of the cross deck structure is to be checked for the loadings specified in this Section, *see also* 5.3.

4.1.2 Other values may be used provided they are verified by model experiments, full scale measurements or any other generally accepted theories. Full details are to be submitted for appraisal.

4.1.3 L_R and T are as defined in Pt 3, Ch 1,6.

4.2 Global loads for multi-hull craft with partially submerged hulls

4.2.1 The twin hull transverse bending moment, M_B, about a longitudinal axis is given by:

$$M_B = G_f\, b\, \Delta\, a_v \text{ kNm}$$

where
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6
b = transverse distance, in metres, between the centre of the two hulls
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,35 for G2A
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2.

4.2.2 The twin hull torsional connecting moment, M_T, is given by:

$$M_T = G_f\, \Delta\, L_R\, a_v \text{ kNm}$$

where
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,70 for G2A
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.2.3 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$$Q_T = G_f\, \Delta\, a_v \text{ kN}$$

where
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,35 for G2A
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

4.3 Global loads for multi-hull craft with fully submerged hulls

4.3.1 The design side force acting at mid-draught of the hull is given by:

$$F_{FS} = G_f\, T\, \Delta^{2/3}\, \Psi_1\, \Psi_2 \text{ kN}$$

where
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 8,5 for G1 and G2
= 9,4 for G2A
= 10,2 for G3
= 13,6 for G4
= 17,0 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
Ψ_1 = $1,55 - 0,75\tanh(\Delta/11000)$
Ψ_2 = $0,75 + 0,35\tanh(1,64 L_S\, \Delta^{-1/3} - 6)$
L_S = strut length, in metres, at waterline.

4.3.2 The lateral pressure acting on the outboard hull may be assumed to be constant and is given by:

$$P_{FS} = \frac{F_{FS}}{A_{FS}} \text{ kN/m}^2$$

where A_{FS} is the projected area, in m^2, of the struts with length L_S at waterline at draught T.

4.3.3 The design transverse bending moment, M_B, due to the side force is given as:

$$M_B = F_{FS}(F + 0{,}5T) \text{ kNm}$$

where F is the distance, in metres, from the waterline to the top of cross structure.

4.3.4 The twin hull torsional connecting moment, M_T, is given by:

$$M_T = G_f\, \Delta\, L_R\, a_v \text{ kNm}$$

where
G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 0,63 for G1 and G2
= 0,70 for G2A
= 0,75 for G3
= 1,00 for G4
= 1,25 for G5 and G6
Δ = displacement, in tonnes, as defined in Ch 2,2.2.2
a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6
L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6

4.3.5 The vertical shear force, Q_T, at the centreline of the cross-deck structure between the twin hulls is given by:

$Q_T = G_f \Delta a_v$ kN

where

G_f = service group factor, *see* Pt 1, Ch 2,3.5.5
= 1,25 for G1 and G2
= 1,35 for G2A
= 1,50 for G3
= 2,00 for G4
= 2,50 for G5 and G6

Δ = displacement, in tonnes, as defined in Ch 2,2.2.2

a_v = the vertical acceleration as defined in Ch 2,3.2, *see also* 1.1.6.

Section 5
Design criteria and load combinations

5.1 Hull girder design criteria for mono-hull craft

5.1.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of ($M_w + M_S$), as defined in 2.2 and 2.3 and M_{DW}, as defined in 2.6, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, is to be taken as the greater of ($Q_w + Q_S$), as defined in 2.4 and 2.5 and Q_{DW}, as defined in 2.6, taking into account of the hogging and sagging conditions.

5.1.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as ($M_w + M_S$), as defined in 2.2 and 2.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as ($Q_w + Q_S$), as defined in 2.4 and 2.5, taking into account the hogging and sagging conditions.

5.1.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.2 Hull girder design criteria for multi-hull craft

5.2.1 The Rule bending moment, M_R, and associated shear forces, Q_R, for non-displacement craft are to be determined as follows:

(a) The Rule bending moment, M_R, is to be taken as the greater of M_{MW}, as defined in 3.2 and M_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as the greater of Q_{MW}, as defined in 3.2 and Q_{MDW}, as defined in 3.3, taking into account the hogging and sagging conditions.

5.2.2 The Rule bending moment, M_R, and associated shear forces, Q_R, for displacement craft are taken to be the greater of the following:

(a) The Rule bending moment, M_R, is to be taken as M_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

(b) The Rule shear forces, Q_R, are to be taken as Q_{MW}, as defined in 3.2, taking into account the hogging and sagging conditions.

5.2.3 L_R and B are as defined in Pt 3, Ch 1,6. Γ and Δ are defined in Ch 2,2.1.17 and Ch 2,2.2.2 respectively.

5.3 Primary load combinations applicable to the cross-deck structure of multi-hull craft

5.3.1 If the global load criteria given in this Chapter are utilised to check cross-deck strength against ductile failure modes involving gross deformation, the following load combinations are to be considered depending on heading of the craft:

(a) Head sea
$0,1M_B + M_R + 0,1M_T$

(b) Beam sea
$M_B + 0,1M_R + 0,2M_T$

(c) Quartering sea
$0,1M_B + 0,4M_R + M_T$

M_B, M_T and M_R are to be taken from 4.2.1, 4.2.3 and 5.2 for multi-hull craft with partially submerged hulls.

M_B, M_T and M_R are to be taken from 4.3.1, 4.3.3 and 5.2 for multi-hull craft with fully submerged hulls.

5.3.2 The strength calculations are, in general, to be conducted using the finite element analysis techniques with a three dimensional model.

Section 6
Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every craft to enable the Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

6.1.2 This information is to be provided by means of a Loading Manual and in addition, where required, by means of an approved loading instrument.

6.1.3 An Operational manual which contains the craft's assigned operational envelope is to be provided on board, *see* Pt 1, Ch 2,2 and Ch 1,1.

6.2 Loading Manuals

6.2.1 A Loading Manual is to be supplied to all craft where longitudinal strength calculations have been required, *see* Ch 5,1. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the craft and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.
(b) The allowable local loadings for the structure.
(c) Details of cargo carriage constraints imposed by the use of an accepted coating in association with a system of corrosion control.
(d) A note saying:
‘Scantlings approved for minimum draught forward of …m with ballast tanks No … filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.’

6.2.5 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved type loading instrument is to be provided for craft when it is deemed necessary by Lloyd’s Register (hereinafter referred to as LR).

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with LR’s *Approval of Longitudinal Strength and Stability Calculation Programs.*

6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 A notice is to be displayed on the loading instrument stating:

‘Scantlings approved for minimum draught forward of ... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.’

6.3.5 Where alteration to structure, lightweight or cargo distribution is proposed, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in Pt 1, Ch 3. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided as an Owner’s option, it is recommended that the system be certified in accordance with LR’s document entitled *Approval of Longitudinal Strength and Stability Calculation Programs.* For systems having a stability computation capability and installed on a new ship, *see also* Pt 1, Ch 2,1.1.10. For systems having a stability computation capability and installed on an existing craft, it is recommended that the system be certified in accordance with LR's document entitled, *Approval of Longitudinal Strength and Stability Calculation Programs.*

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Hull Construction in Ships
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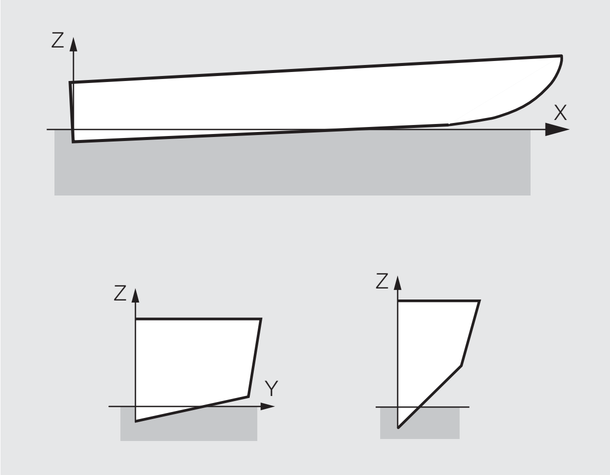
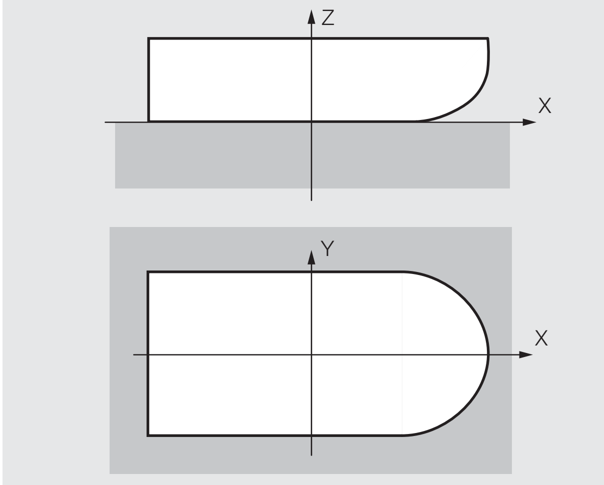
Lloyd's Register
LIFE MATTERS

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

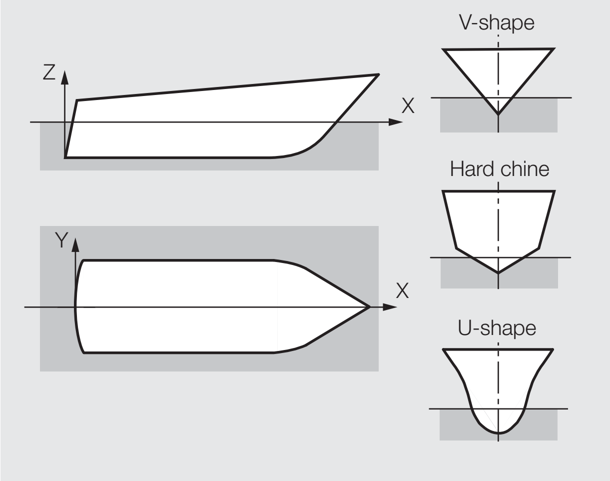
PLANING CRAFT



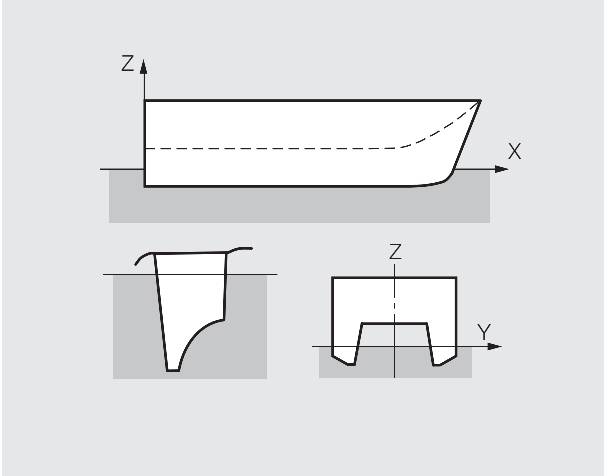
HOVERCRAFT



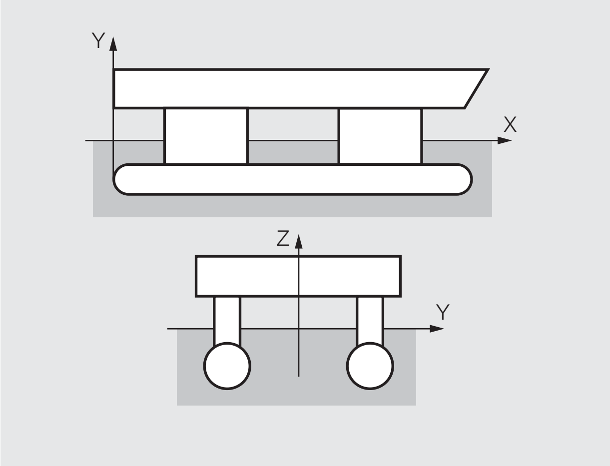
DISPLACEMENT CRAFT



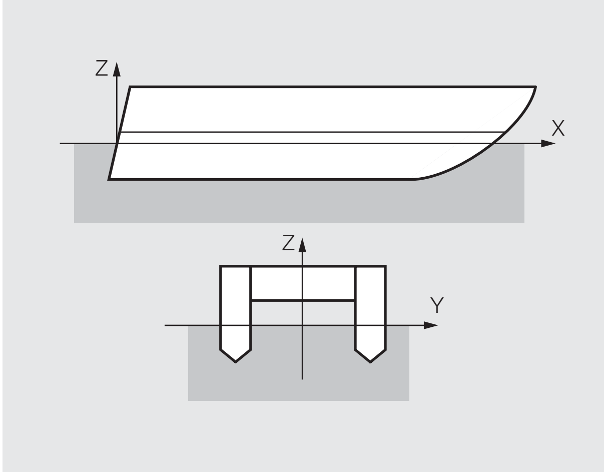
SURFACE EFFECT SHIP



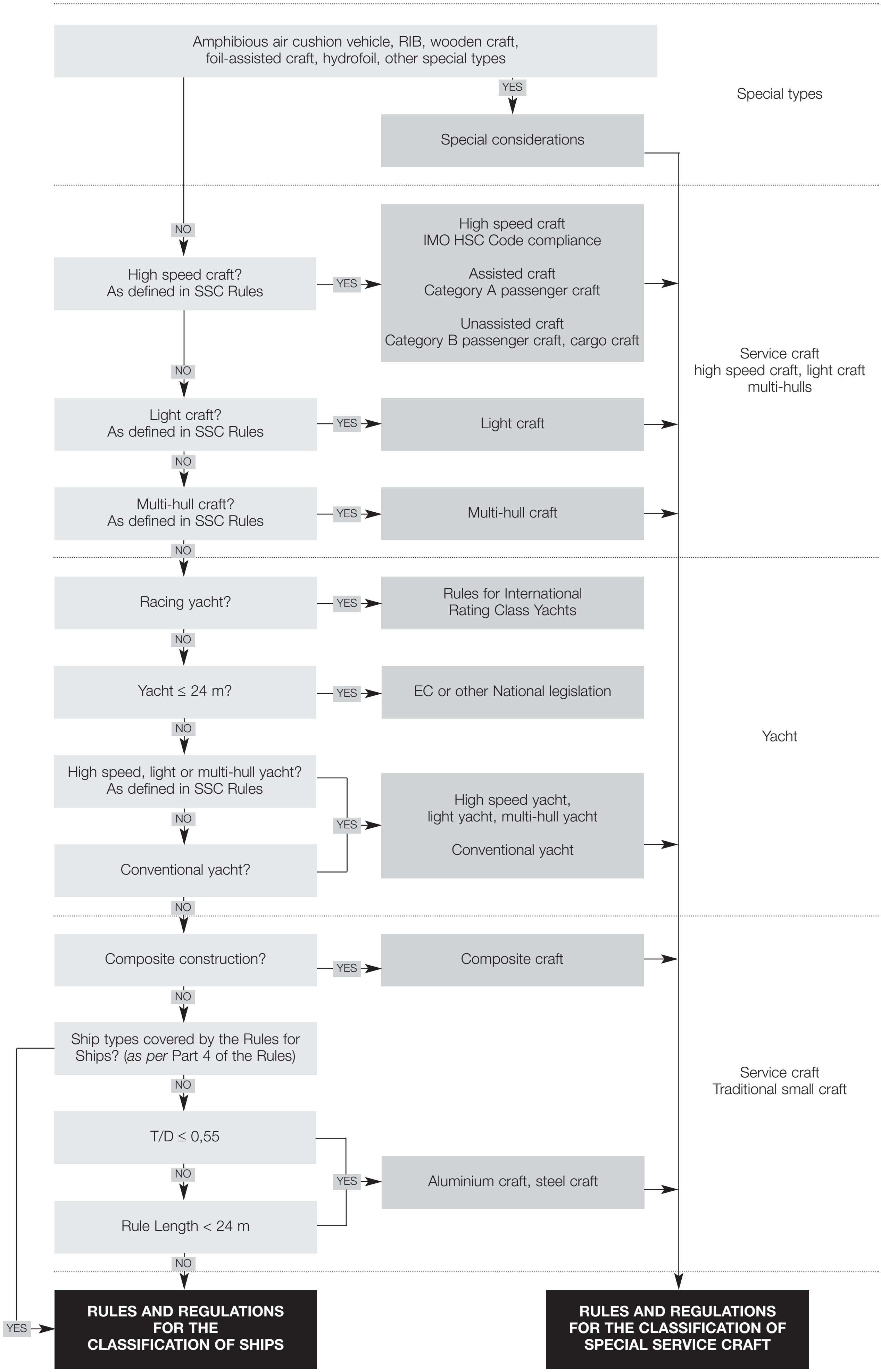
SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section 1
Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for steel craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builders' and/or designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2
General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or a single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings, and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.

- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of steel has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiff end flat panels, *see* Ch 1,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel craft using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's Quality Assurance Scheme for the Construction of Special Service Craft.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the following activities:

  (i) Receipt storage and issue of materials, equipment, etc.
  (ii) Fabrication environment.
  (iii) Weld procedures and welder performance.
  (iv) Production fabrication.
  (v) Inspection of production processes.
  (vi) Installation of machinery and essential systems.
  (vii) Fitting-out.
  (viii) Tests and trials.
  (ix) Drawings and document control.
  (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Periodical Survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deck head and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* **Materials**

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of steel which is being supplied and for the relevant steel production and processing route.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with Ch 3,8 of the Rules for Materials.

2.3 Steel castings and forgings

2.3.1 Where steel castings or forgings are used for stern-frames, rudder frames, rudder stocks, propeller shaft brackets and other major structural items, they are to comply with Chapter 4 or Chapter 5, as appropriate.

2.4 Mechanical properties for design

2.4.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200×10^3

2.4.2 Steel having a specified minimum yield stress of 235 N/mm^2 (24 kgf/mm^2) is regarded as mild steel. Steel having a higher specified minimum yield stress is regarded as higher tensile steel.

2.4.3 The requirements for global strength considerations in craft incorporating higher tensile steel materials are to be based on a material efficiency factor, η_{HTS}, as given in Table 2.2.1.

Table 2.2.1 Values of η_{HTS}

Specified minimum yield stress in N/mm^2	η_{HTS}
235	1,000
265	0,964
315	0,956
340	0,934
355	0,919
390	0,886
NOTE Intermediate values by interpolation.	

2.4.4 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_s}$$

or 0,66 whichever is the greater

where

σ_s = specified minimum yield strength of material, in N/mm^2.

2.4.5 For the application of the requirements of 2.4.3 and 2.4.4 special consideration will be given to steel where $\sigma_s \geq 390$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.5 Corrosion protection

2.5.1 All steelwork, except inside integral fuel tanks, is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.5.2 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating. It is recommended that blast cleaning, or other equally effective means, be employed for this purpose.

2.5.3 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.6 Paints and coatings

2.6.1 The hull is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section.

2.6.2 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.4 Integral fuel tanks are to be cleaned and dried, after testing, and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.6.6 Protective coatings are generally to be hard coatings. Other coating systems (e.g. soft coatings) may be considered as alternatives provided they are applied and maintained in compliance with the manufacturer's specification.

2.6.7 The paint or coating is to be compatible with any previously applied primer, *see* 2.6.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of, and connections to the hull, bulkheads and decks by piping and, equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 External immersed areas

2.9.1 For the deferment of dry docking or where an **IWS** (In-water Survey) notation is to be assigned protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information.

2.10 External cathodic protection

2.10.1 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes, reference cells, wiring diagram and the means of bonding-in of the rudder and propeller, are to be submitted.

2.10.2 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks containing low flash point oils.

2.11 Protection of ballast spaces

2.11.1 Cathodic protection may be used in association with coatings for the protection of ballast spaces.

2.11.2 The anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.11.3 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.
(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.
(c) Approved means of mechanical clamping.

2.11.4 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.11.5 Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.12 Deck coverings

2.12.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.12.2 Deck coverings in the following positions are to be of a type which will not readily ignite when used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.13 Corrosion margin

2.13.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.13.2 Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.14 Fracture control

2.14.1 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.14.2 High local stresses are to be avoided by the use of suitable design detail. *See also* LR's *Guidance Notes for Structural Details*.

2.14.3 The resistance to fracture is controlled, in part, by the notch toughness of the steel used in the structure. Steels with different levels of notch toughness are specified in the Rules for Materials. The grade of steel to be used is, in general, related to the thickness of the material and the stress pattern associated with its location.

2.14.4 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, as detailed in Ch 3,8 of the Rules for Materials.

2.14.5 For craft operating for long periods in low air temperature the material of exposed structures will, in general, be specially considered.

■ *Section 3* Procedures for welded construction

3.1 General

3.1.1 All welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Defined practices and welding sequence

3.3.1 Rudder, sterntubes, propeller brackets and jet units. The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4 Structural arrangements and access

3.4.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5 Inspection

3.5.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.5.2 Checkpoints examined at the pre-fabrication stage are to include ultrasonic testing on examples of the stop/start points of automatic welding and magnetic particle inspections of weld ends.

3.5.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.6 Acceptance criteria

3.6.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.5.3		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: • hull envelope • longitudinal and transverse bulkheads • inner bottom and hopper bottom	The summation of checkpoint lengths, *see* Note 2, examined at intersections is to be *L*, where *L* is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4*L* amidships Hull envelope outside 0,4*L* amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: • connection of stool and bulkhead to lower stool shelf plating • vertical corrugations to an inner bottom • hopper knuckles • sheerstrake to deck stringer • hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

■ *Section 4* Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.24.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

Throat thickness $= t_p \times \text{weld factor} \times \left(\frac{d}{s}\right)$ mm

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillet, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.6

Weld factors are contained in Table 2.4.1.

NOTE

For double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1, *see* 4.8.1.

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5, *see* Fig. 2.4.1.

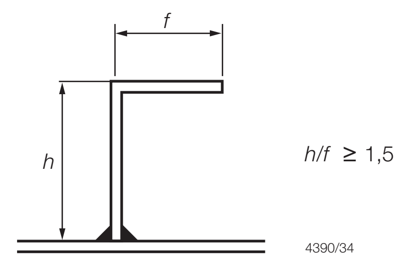


Fig. 2.4.1 Web height/flange breadth ratio

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in 4.5.2 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.2 are to be complied with.

4.7 Double continuous fillet welding

4.7.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.2 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.7.2 Double continuous fillet welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine seatings.
(d) Bottom framing structure in machinery spaces of high speed craft.
(e) The side and bottom shell structure in the impact area of high speed motor craft.
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.
(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.
(h) The shell structure in the vicinity of the propeller blades.
(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

4.8 Intermittent fillet welding (staggered)

4.8.1 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.9 Intermittent fillet welding (chain)

4.9.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Single sided fillet welding

4.10.1 Continuous single sided fillet welding may be used in lieu of intermittent fillet welding (staggered and chain), outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Connections of primary structure

4.11.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.1.

Table 2.4.1 **Weld factors** (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
Watertight plate boundaries	0,34	
Non-tight plate boundaries	0,13	
Longitudinals,frames,beams, and other secondary members to shell, deck or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
Panel stiffeners	0,10	
Overlap welds generally	0,27	
(2) Bottom construction:		
Non-tight centre girder: to keel to inner bottom	0,27 0,21	 no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
Connection of floors to inner bottom where bulkhead is supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
Webs of web frames and stringers: to shell to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
Weather deck plating to shell	0,44	
Other decks to shell and bulkheads (except where forming tank boundaries)	 0,21	 generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	 0,44	
Webs of cantilevers to face plate	0,21	
Girder webs to deck clear of end brackets	0,10	
Girder webs to deck in way of end brackets	0,21	
Web of girder to face plate	0,10	
Pillars: fabricated end connections end connections (tubular)	0,10 0,34 full penetration	
Girder web connections and brackets in way of pillar heads and heels	 0,21	 continuous

4.11.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \text{ x stiffener spacing}}{\text{length of web plating between notches}}$$

4.11.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

Table 2.4.1 Weld factors (*continued*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
Plane and corrugated watertight bulkhead boundary at bottom , bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	weld size to be based on thickness of bulkhead plating weld material to be compatible with bulkhead plating material
Secondary members, where acting as pillars	0,13	
Non-watertight pillar bulkhead boundaries	0,13	
Perforated flats and wash bulkhead boundaries	0,10	
Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
Floors to centre girder in way of engine thrust bearers	0,27	
Floors and girders to shell and inner bottom	0,21	
Main engine foundation girders: to top plate to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0{,}33t_p$ deep penetration generally
Floors to main engine foundation girders	0,27	
Brackets, etc., to main engine foundation girders	0,21	
Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
Internal bulkheads	0,13	
(8) Steering control systems:		
Rudder: Fabricated mainpiece and mainpiece to side plates and webs	0,44	
Slot welds inside plates	0,44	
Remaining construction	0,21	
Fixed and steering nozzles: Main structure Elsewhere	0,44 0,21	
Fabricated housing and structure of thruster units, stabilisers, etc.: Main structure Elsewhere	0,44 0,21	

Table 2.4.1 Weld factors *(conclusion)*

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
Rings for manhole type covers, to deck or bulkhead	0,34	
Frames of shell and weathertight bulkhead doors	0,34	
Stiffening of doors	0,21	
Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Position 1 and 2 elsewhere
Ventilator, etc., fittings	0,21	
Scuppers and discharges, to deck	0,44	
Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
Deck machinery seats to deck	0,21	generally
Mooring equipment seats	0,21	generally, but increased or full penetration may be required
Bulwark stays to deck	0,21	
Bulwark attachment to deck	0,34	
Guard rails, stanchions, etc., to deck	0,34	
Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
Fabricated anchors	full penetration	

Table 2.4.2 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0,21t_p$	$0,44t_p$
(2) Intermittent welding	$0,27t_p$	$0,44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	—
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7,5$ mm		
Hand or automatic welding	3,0	—
Automatic deep penetration welding	3,0	—
(ii) Plate thickness $t_p \geq 7,5$ mm Hand or automatic welding	3,25	—
Automatic deep penetration welding	3,0	—

NOTES
1. In all cases the limiting value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.12 Primary and secondary member end connection welds

4.12.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.12.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.3. Where two requirements are given the greater is to be complied with.

4.12.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.12.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.13 Weld connection of strength deck plating to sheerstrake

4.13.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

Table 2.4.3 Secondary member end connection welds

Connection	Weld area, A_W, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_S$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	–	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	–	0,34

Symbols

A_S = cross section area of the stiffener, in cm^2
A_W = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm
Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based

NOTE
For maximum and minimum weld fillet sizes, *see* Table 10.2.2.

4.14 Air and drain holes

4.14.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. *See also* LR's *Guidance Notes for Structural Details*.

4.15 Notches and scallops

4.15.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to well rounded with smooth edges.

4.15.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

4.16 Watertight collars

4.16.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries. *See also* LR's *Guidance Notes for Structural Details*.

4.17 Lug connections

4.17.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.2 and Fig. 3.1.7 in Chapter 3.

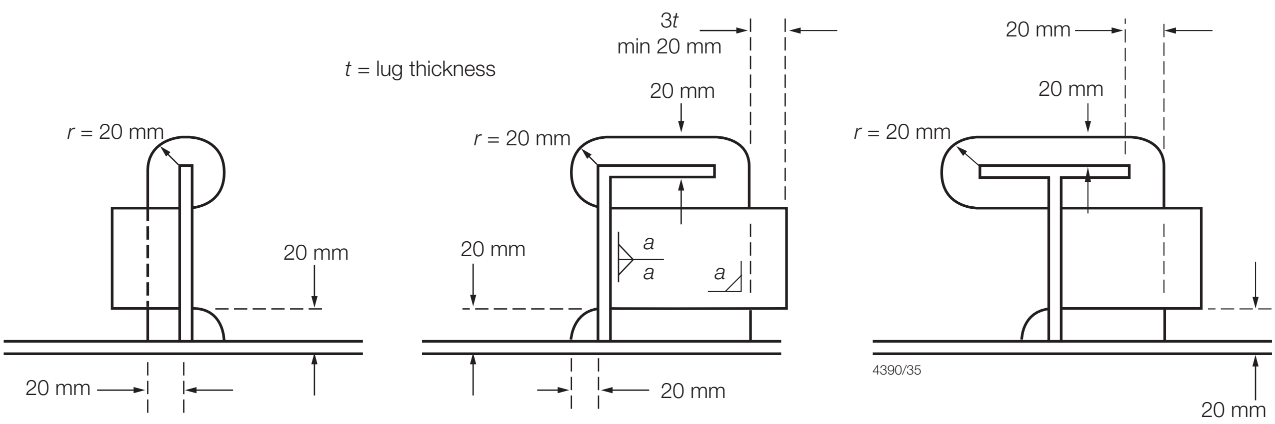


Fig. 2.4.2 Typical lug connections

4.17.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.17.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.18 Insert plates

4.18.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.18.2 The corners of insert plates are to be suitably radiused.

4.19 Doubler plates

4.19.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.19.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.20 Joint preparation

4.20.1 Typical butt joints are shown in LR's *Guidance Notes for Structural Details*.

4.21 Construction tolerances

4.21.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.22 Riveting of light structure

4.22.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.22.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

4.22.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.22.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.22.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.22.6 Sealing paints or compounds are not to be used with hot driven rivets.

4.23 Chemical bonding of structure

4.23.1 Where chemical bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.23.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.23.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.23.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.23.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.23.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.24 Triaxial stress considerations

4.24.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.25 Aluminium/Steel transition joints

4.25.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.25.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.25.3 The steel material is to comply with the requirements of Section 2 and the aluminium is to be of an appropriate grade complying with the requirements of Chapter 8 of the Rules for Materials.

4.25.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.24.3 or are approved for a specific application.

4.25.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.25.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.26 Steel/Wood connection

4.26.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

Section

Section 1
General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of steel construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6

Z = section modulus of stiffening member, in cm^3

I = moment of inertia, in cm^4

A_w = shear area of stiffener web, in cm^2

l = stiffener overall length, in metres

l_e = effective span length, in metres, as defined in 1.19

p = design pressure, in kN/m^2 as given in Part 5

s = stiffener spacing, in mm

t_p = plating thickness, in mm

β = panel aspect ratio correction factor as defined in 1.15

γ = convex curvature correction factor as defined in 1.14

k_s = high tensile steel factor
= $235/\sigma_s$, *see also* Ch 2,2.4

σ_s = guaranteed minimum yield strength of the material, in N/mm^2

$$\tau_s = \frac{\sigma_s}{\sqrt{3}}$$

E = modulus of elasticity, in N/mm^2.

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Shipowner and Shipbuilder may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235
Tensile strength	400 – 490
Modulus of elasticity	200 x 10^3.

1.9 Higher tensile steels

1.9.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.9.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness and stiffener section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_s}$

(b) Section modulus and cross-sectional area factor = k_s

where

k_s is as defined in 1.5.1.

1.9.3 The minimum moment of inertia of higher tensile steel stiffening members is to be not less than that required for mild steel stiffening members.

1.9.4 For determination of hull girder section modulus in craft incorporating higher tensile steel materials, *see* Ch 6,2.2.1, 2.2.2 and Ch 2,2.4.3.

1.10 Effective width of attached plating

1.10.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.10.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e in mm. b_e is as defined in 1.10.3 and 1.10.4.

1.10.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p \sqrt{E/\sigma_s}$ but not greater than s. σ_s is not to be taken as greater than 235 N/mm^2 for mild steel or 340 N/mm^2 for higher tensile steel. E, s and σ_s are as defined in 1.5.1.

1.10.4 The effective breadth of attached plating to primary support members (girders, transverses, webs etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2, 3.2.1.

1.11 Other materials

1.11.1 Special consideration will be given to the use of materials other than steel. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.12 Aluminium alloys

1.12.1 The use of aluminium alloys in construction is to be in accordance with Part 7.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7,
h = the distance, in mm, measured perpendicularly from the chord length, s, (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.1.

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R(1 - 0{,}25A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$
A_R = panel aspect ratio
= panel length/panel breadth.

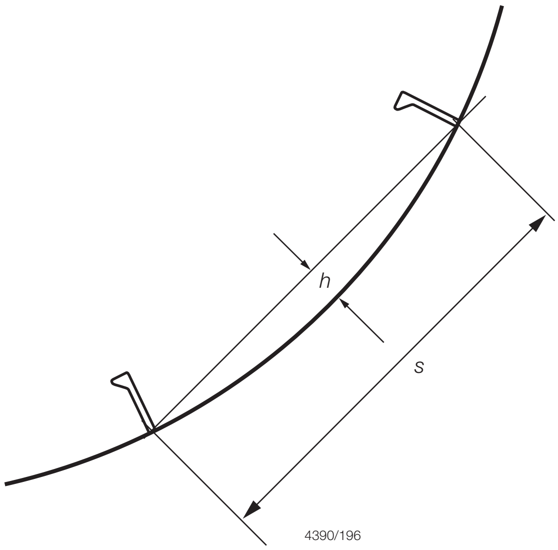


Fig. 3.1.1 Convex curvature

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4\, s\, \gamma\, \beta \sqrt{\frac{p}{f_\sigma\, \sigma_s}} \times 10^{-3} \text{ mm}$$

where

f_σ = limiting bending stress coefficient for the plating element under consideration given in Table 7.3.1 in Chapter 7.

s, γ, β, p, σ_s are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are, in general, to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\, s\, l_e^2}{f_\sigma\, \sigma_s} \text{ cm}^3$$

where

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1

f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.

p, s, l_e, and σ_s are as defined in 1.5.1.

(b) Inertia:

$$I = \Phi_I\, f_\delta \frac{p\, s\, l_e^3}{E} \times 100 \text{ cm}^4$$

where

Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1

f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.

p, s, l_e, and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\, s\, l_e}{100\, f_\tau\, \tau_s} \text{ cm}^2$$

where

Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1

f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7

p, s, l_e, and τ_s are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

1.19 Determination of span point

1.19.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:
The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:
The span point is to be taken at a point distant, b_e, from the end of the member

$$b_e = b_b \left(1 - \frac{d_w}{d_b}\right)$$

where

b_e, b_b, d_w and d_b are as shown in Fig. 3.1.2.

1.19.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

Table 3.1.1 Section modulus, inertia and web area coefficients

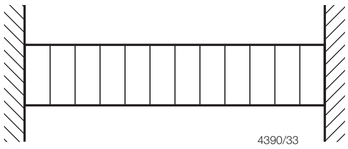
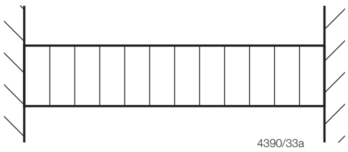
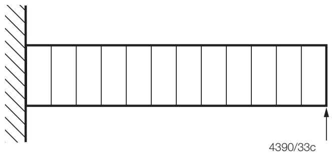
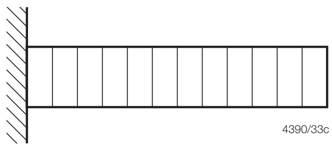
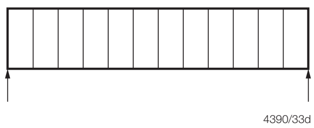
Load model	Position			Position	Web area coefficient	Section modulus coefficient	Inertia coefficient	Application
	1	2	3		Φ_A	Φ_Z	Φ_I	
(a)				1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)				1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)				1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)				1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)				1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/18 \quad \geq 2,5$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/65 \quad \geq 2,5$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.10 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

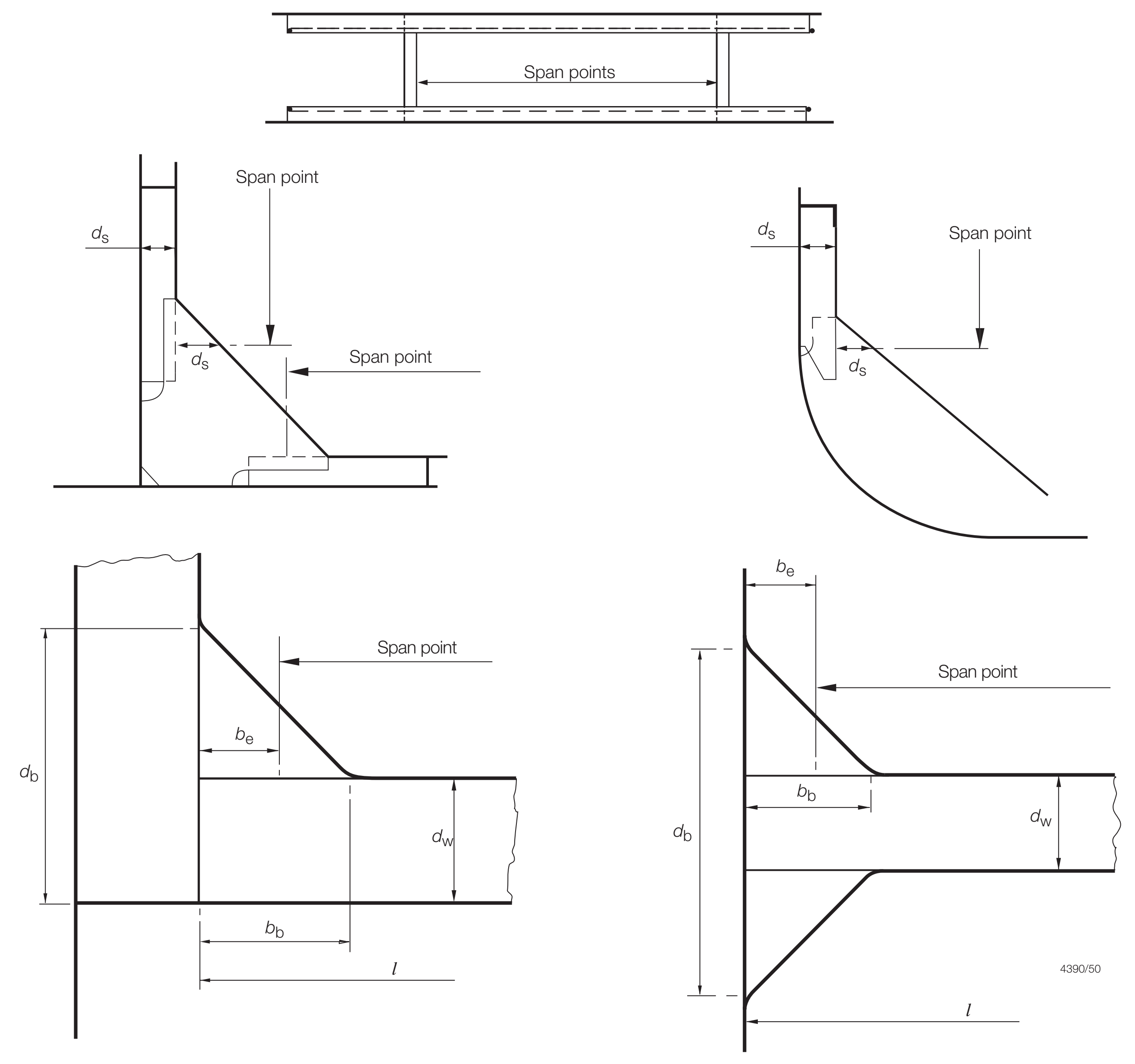


Fig. 3.1.2 Span points

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.
(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, a and b, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0l_b$
(b) $a \geq 0{,}8l_b$
(c) $b \geq 0{,}8l_b$

where a and b are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}} - 1\right) \text{ mm}$$

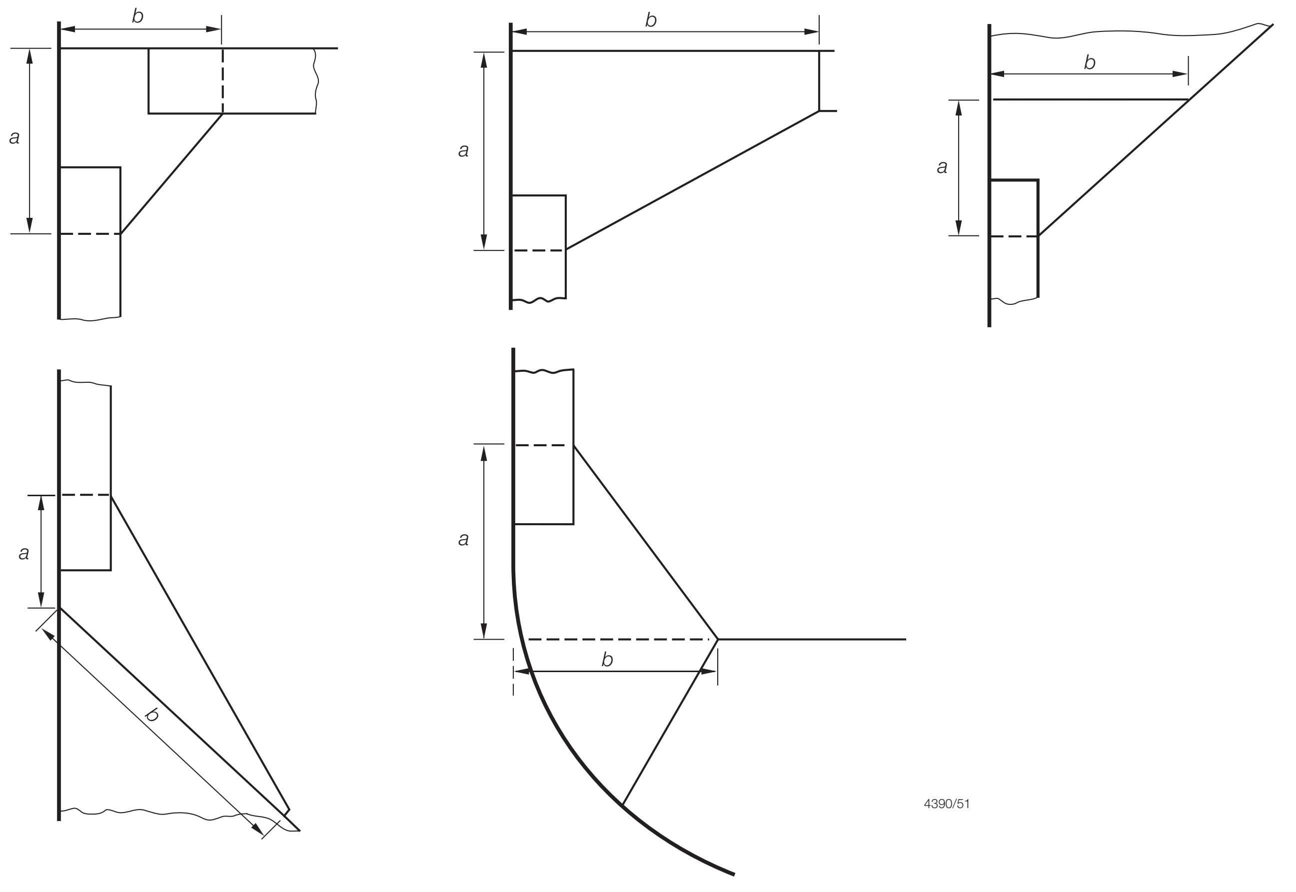


Fig. 3.1.3 Stiffener end brackets

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 500 cm^3.

(b) The length of free edge exceeds 40 times the bracket thickness.

(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 40\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 50 mm

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}009 k_s\, b_f\, T_B$ cm^2 for offset edge stiffening.

(b) $0{,}014 k_s\, b_f\, T_B$ cm^2 for symmetrically placed stiffening

where

b_f = breadth of face flat, in mm

T_B = the thickness of the bracket, in mm

k_s is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking *Z* as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

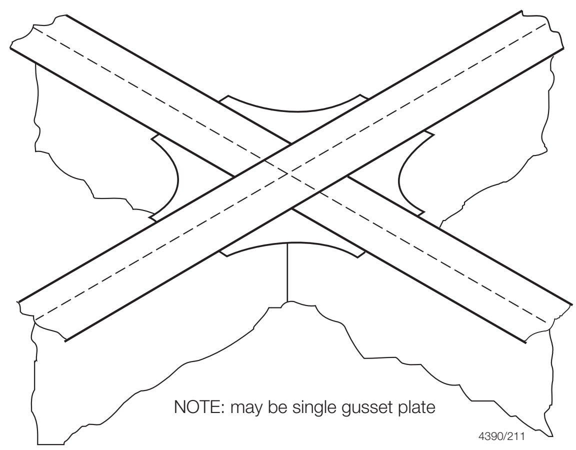


Fig. 3.1.4 Primary member intersection

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off. *See also* LR's *Guidance Notes for Structural Details*.

1.26.7 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

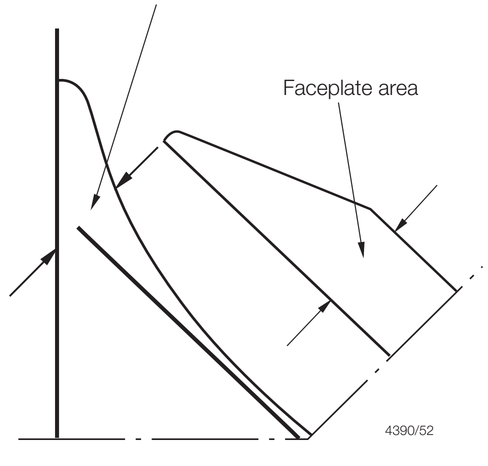


Fig. 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see* Fig. 3.1.6) the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

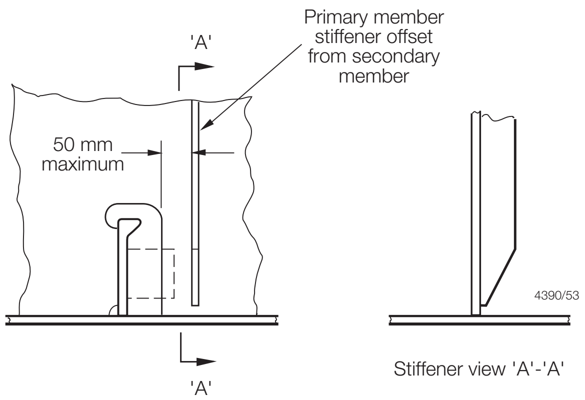


Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration. *See also* LR's *Guidance Notes for Structural Details*.

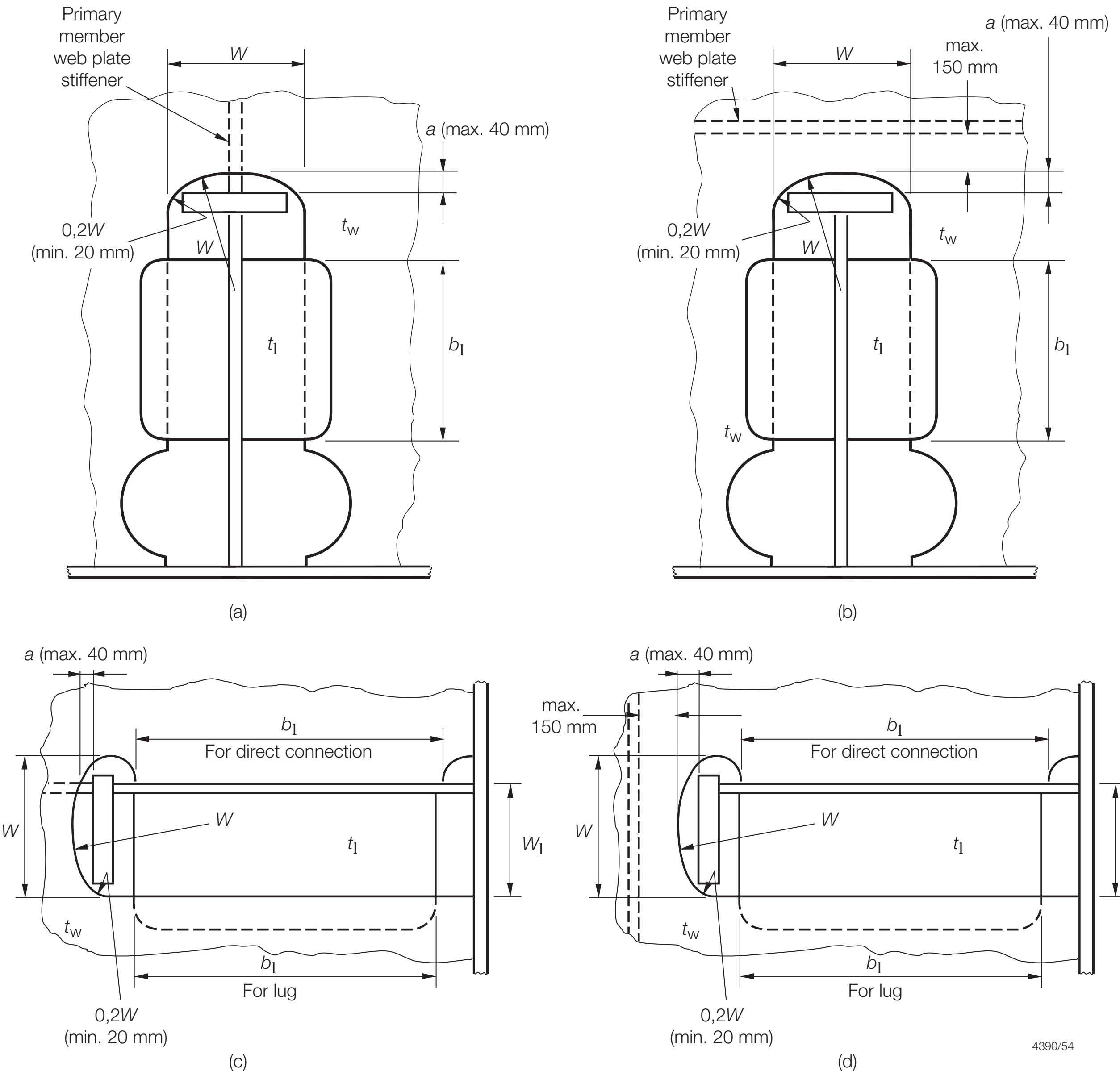


Fig. 3.1.7 Cut-outs and connections

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with, the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Chapter 13 of the Rules for Materials.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not fitted in the forward 0,3L_R region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 6 mm, whichever is the greater, but need not be taken as greater than 12 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

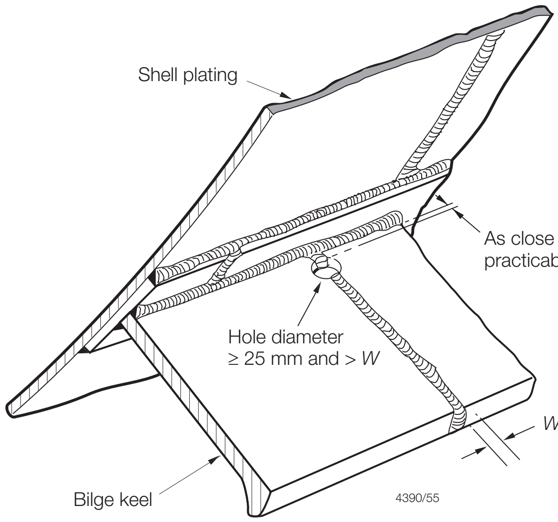


Fig. 3.1.8 Bilge keel construction

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone ‘A’ (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone ‘A’, *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone ‘B’ (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

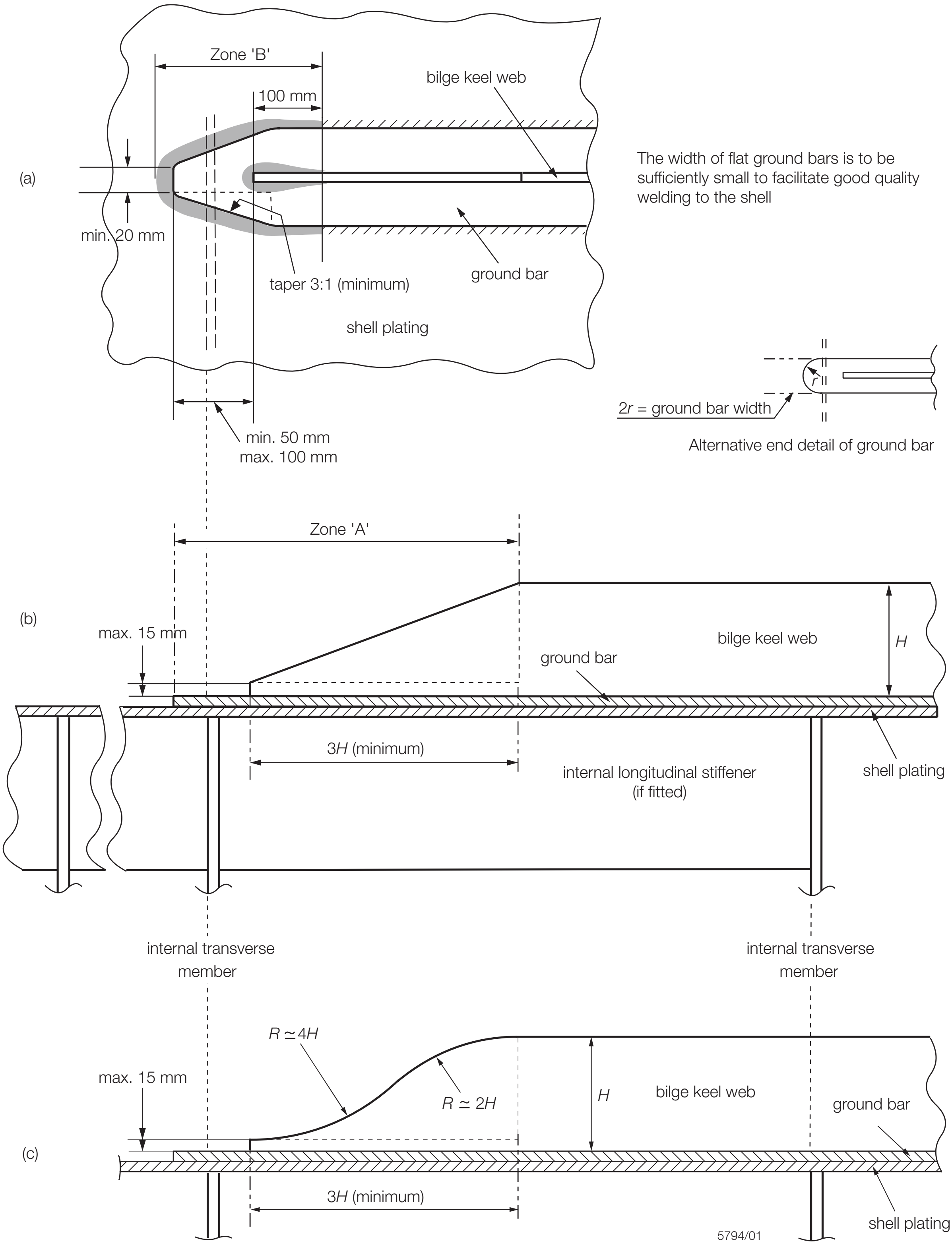


Fig. 3.1.9 Bilge keel end design

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web provided the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion, e.g. from passenger routes, working areas of fishing vessels, forefoot region, etc., are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_{ms}}\,(0{,}4\sqrt{L_R} + 2{,}0) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}4\sqrt{L_R} + 2{,}0) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}4\sqrt{L_R} + 2{,}0) \geq 3{,}5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$
Double bottom structure			
Centre girder			
(1) Within $0{,}4L_R$ amidships	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\sqrt{k_{ms}}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R} + 0{,}8) \geq 3{,}5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\,(0{,}5\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}5\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}5\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$
Bulkheads			
Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R} + 1{,}0) \geq 2{,}5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R} + 1{,}2) \geq 3{,}0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R} + 1{,}7) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R} + 1{,}7) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R} + 1{,}7) \geq 2{,}0\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R} + 1{,}0) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R} + 1{,}0) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R} + 1{,}0) \geq 2{,}0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\,(0{,}47\sqrt{L_R} + 1{,}5) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}47\sqrt{L_R} + 1{,}5) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}47\sqrt{L_R} + 1{,}5) \geq 3{,}0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\,(0{,}42\sqrt{L_R} + 1{,}3) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}42\sqrt{L_R} + 1{,}3) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}42\sqrt{L_R} + 1{,}3) \geq 3{,}0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\,(0{,}2\sqrt{L_R} + 0{,}6) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}2\sqrt{L_R} + 0{,}6) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}2\sqrt{L_R} + 0{,}6) \geq 2{,}0\omega$
Pillars			
Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\;0{,}05d_p$	$\omega\sqrt{k_{ms}}\;0{,}05d_p$	$\omega\sqrt{k_{ms}}\;0{,}05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\;0{,}05b_p$	$\omega\sqrt{k_{ms}}\;0{,}05d_p$	$\omega\sqrt{k_{ms}}\;0{,}05d_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2
k_{ms} = $635/(\sigma_s + \sigma_u)$
σ_s = specified minimum yield strength of the material, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R is as defined in 1.5.1.

Table 3.2.2 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

■ *Section 3*
Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$

$$t_k = \sqrt{k_s}\; 1{,}35L_R^{0{,}45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_S, is not to be taken as less than:

$$t_s = \sqrt{k_s}\; (0{,}1L_R + 3) \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating, *see* Fig. 3.3.1, as detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

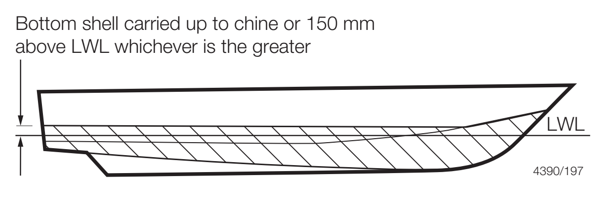


Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of 0,33L_R or 500 mm aft of the point at which the deckline reaches its greatest breadth, whichever is the greater and forward of the quarter and over the transom for a distance of 0,075L_R or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantlings as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc., the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc.; details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius is, in general, to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding 0,15L_R, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details.*

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for solepieces given in Pt 3, Ch 3,3.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimize stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater.

3.13 Local reinforcement/Insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes, anchor recess, etc. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.22.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are, in no case, to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point, the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this, full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28, respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 **For craft**, including pilot boats and fishing vessels, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will be given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5* Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_s (L_R + 1) \text{ cm}^2$$
$$t_k = \sqrt{k_s}\ (0{,}5L_R + 6) \text{ mm}$$

where
L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is in general to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = \sqrt{k_s}\left(\sqrt{L_R} + 1\right) \text{ mm}$$

where
L_R and k_s are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$A_f = 0{,}3 L_R\, k_s \text{ cm}^2$

where

L_R and k_s are as defined in 1.5.1.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$t_w = \sqrt{(k_s\, L_R)} \text{ mm}$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web frame and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.6

B is as defined in 1.5.1.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$A_f = k_s\, 0{,}15L_R \text{ cm}^2$

where

k_s and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_W, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent, but need not be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending, Z_r, at any horisontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z_r = 1{,}5 k_s R_A K_V (V + 3)^2 \sqrt{a^2 + 0{,}5b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $V/\sqrt{L_{WL}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $V/\sqrt{L_{WL}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

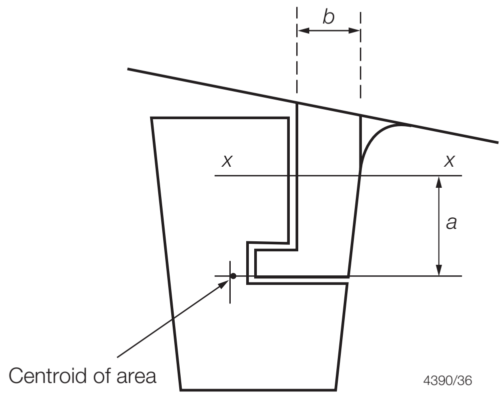


Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid sternframes are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of steel in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to withstand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}8 k_s L_R \quad \text{cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

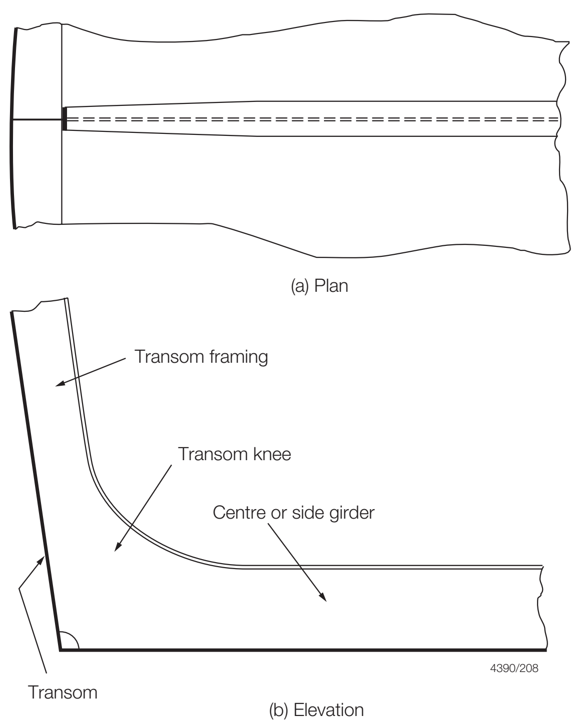


Fig. 3.5.2 Transom knee

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of steel mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t_p = \sqrt{k_s}\,(0{,}008d_{DB} + 1) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

where

d_{DB} is the Rule centre girder depth given in 6.3.3

k_s as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\,(0{,}1L_R + 3) \text{ mm within } 0{,}4L_R \text{ amidships}$$

$$= \sqrt{k_s}\,(0{,}1L_R + 2) \text{ mm at ends.}$$

where

k_s and L_R as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$$t_w = \sqrt{k_s}\ (0{,}05L_R + 3{,}5)\ \text{mm}$$

where

k_s and L_R as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are, in general, to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w,

where

t_w is the thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.10 Inner bottom longitudinals

6.10.1 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.10.2 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Manholes

6.15.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.16 Pressure testing

6.16.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.17 Drainholes in bottom structure

6.17.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.17.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.17.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

Section 7
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_C, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be sub-divided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks are to be cleaned and dried after testing and then treated with a suitable coating, in accordance with the manufacturer's recommendations.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be sufficiently accessible to allow for maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Sufficient space is to be available below lower decks/soles to allow access to the bottom structure. An adequate number of manholes, removable panels, etc., are to provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 metres Rule length, L_R, or in the case where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepeak compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular care is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater. The pressure to which the tanks will be subjected to in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/Weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.4.

8.3 Lower deck/Inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, plating thickness requirements are to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

8.7 Strength/Weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/Inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0,5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2.5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

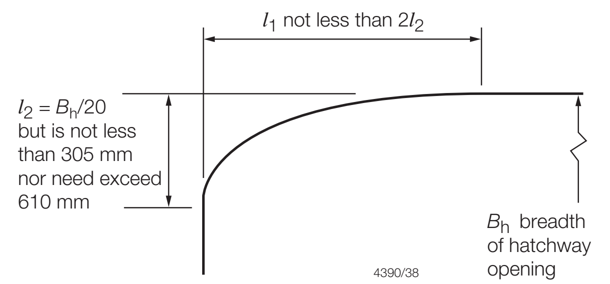


Fig. 3.8.1 Hatch opening geometry

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

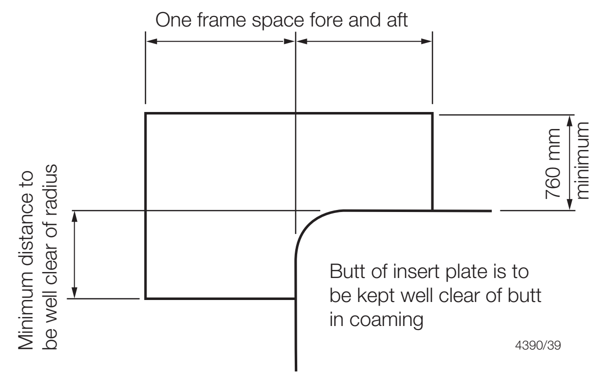


Fig. 3.8.2 Inserts in way of hatch opening

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9*
Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deck-houses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deck-houses and bulwarks is no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term ‘house’ is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of 0,25L_R from the FP. No increase is required if the forecastle end bulkhead lies forward of 0,2L_R from the FP. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for **house top secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for **coachroof primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for **coachroof secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for **machinery casing primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for **machinery casing secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing sides act as girders supporting decks, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.4 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular care is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.24.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also be required to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer-strake within 0,5L_R amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheer-strake thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

■ *Section 10*
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, to be used in the determination of pillar scantlings is as follows:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \text{ kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \text{ cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_s}{1 + 0{,}0051\sigma_s\, k \left(\frac{l_{ep}}{r}\right)^2} \text{ N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_s = specified minimum yield strength of the material, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \sqrt{\frac{I_p}{A_p}} \text{ cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in 10.2.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1. Where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

L_R = Rule length of craft, in metres
s = stiffener spacing, in mm
t_p = plating thickness, in mm
k_s = high tensile steel factor
= $235/\sigma_s$
σ_s = specified minimum yield strength of the material, in N/mm^2.

1.5.2 **Bottom outboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck**. The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch**. The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard**. The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard**. The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck**. The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope			
Bottom shell plating	$\omega\sqrt{k_{ms}}\,(0{,}4\sqrt{L_R}+2{,}0) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}4\sqrt{L_R}+2{,}0) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}4\sqrt{L_R}+2{,}0) \geq 3{,}5\omega$
Side shell plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$
Wet-deck plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$
Single bottom structure			
Centre girder web	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$
Floor webs	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$
Side girder webs	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$
Double bottom structure Centre girder:			
(1) Within $0{,}4L_R$ amidships	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}8\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\sqrt{k_{ms}}\,(0{,}7\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}7\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}7\sqrt{L_R}+1{,}0) \geq 4{,}0\omega$
Floors and side girders	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}6\sqrt{L_R}+0{,}8) \geq 3{,}5\omega$
Inner bottom plating	$\omega\sqrt{k_{ms}}\,(0{,}5\sqrt{L_R}+1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}5\sqrt{L_R}+1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}5\sqrt{L_R}+1{,}0) \geq 2{,}5\omega$
Bulkheads			
Watertight bulkhead plating	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R}+1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R}+1{,}0) \geq 2{,}5\omega$	$\omega\sqrt{k_{ms}}\,(0{,}33\sqrt{L_R}+1{,}0) \geq 2{,}5\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$
Deck plating and stiffeners			
Strength/Main deck plating	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}38\sqrt{L_R}+1{,}2) \geq 3{,}0\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R}+1{,}7) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R}+1{,}7) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}18\sqrt{L_R}+1{,}7) \geq 2{,}0\omega$
Superstructures and deckhouses			
Superstructure side plating	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R}+1{,}0) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R}+1{,}0) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}3\sqrt{L_R}+1{,}0) \geq 2{,}0\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_{ms}}\,(0{,}47\sqrt{L_R}+1{,}5) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}47\sqrt{L_R}+1{,}5) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}47\sqrt{L_R}+1{,}5) \geq 3{,}0\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_{ms}}\,(0{,}42\sqrt{L_R}+1{,}3) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}42\sqrt{L_R}+1{,}3) \geq 3{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}42\sqrt{L_R}+1{,}3) \geq 3{,}0\omega$
Deckhouse aft	$\omega\sqrt{k_{ms}}\,(0{,}2\sqrt{L_R}+0{,}6) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}2\sqrt{L_R}+0{,}6) \geq 2{,}0\omega$	$\omega\sqrt{k_{ms}}\,(0{,}2\sqrt{L_R}+0{,}6) \geq 2{,}0\omega$
Pillars			
Wall thickness of tubular pillars	$\omega\sqrt{k_{ms}}\;0{,}05d_p$	$\omega\sqrt{k_{ms}}\;0{,}05d_p$	$\omega\sqrt{k_{ms}}\;0{,}05d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_{ms}}\;0{,}05b_p$	$\omega\sqrt{k_{ms}}\;0{,}05b_p$	$\omega\sqrt{k_{ms}}\;0{,}05b_p$

Symbols

ω = service type factor as determined from Table 3.2.2 in Chapter 3
k_{ms} = $635/(\sigma_s + \sigma_u)$
σ_s = specified minimum yield strength of the material, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangular pillar, in mm
d_p = outside diameter of tubular pillar, in mm

Section 3
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_s}\ 1{,}35L_R{}^{0{,}45} \text{ mm}$$

where

L_R and k_s are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 3,3.1 or Ch 4,3.1 as appropriate. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations are to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 3 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

4.26.6 Particular attention is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

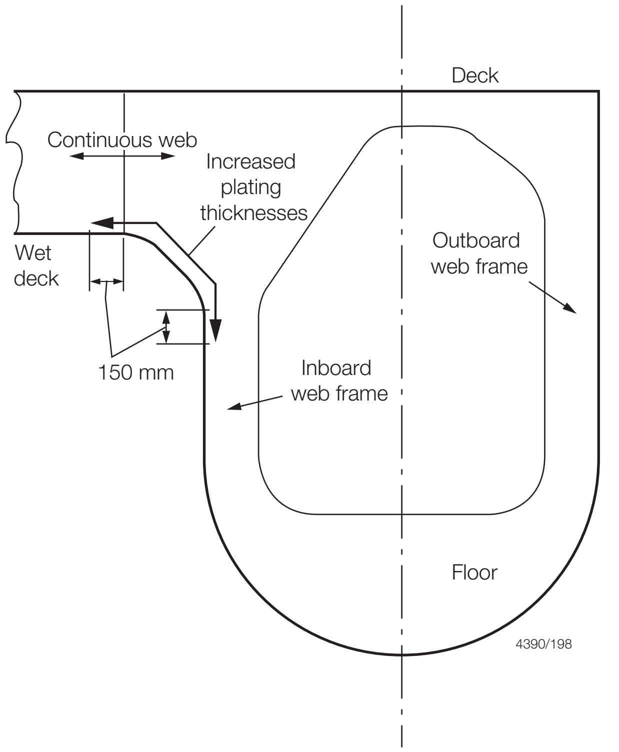


Fig. 4.4.1
End connection details, wet-deck structure

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or Recognised Standard for pressure vessels using the design loading from Pt 5, Ch 4,4.1. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels are not, in general, be taken as less than:

$$A_{bk} = 0{,}75 L_R\, k_s \ \text{cm}^2$$
$$t_{bk} = \sqrt{k_s}\ (0{,}5 L_R + 2)\ \text{mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, of the centre girder is to be taken not less than:

$$t_w = \sqrt{k_s}\ (0{,}8\sqrt{L_R} + 1)\ \text{mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = k_s\, 0{,}22 L_R \ \text{cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness is to be not less than the thickness of the web, t_w, as determined from 5.3.4.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 metres. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girder webs is to be taken as not less than:

$$t_w = \sqrt{(0{,}43 k_s\, L_R)}\ \text{mm}$$

where

L_R and k_s are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deep tanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are in general to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth, d_f, of floors at the centreline, is not to be taken as less than:

$$d_f = 6{,}2L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_s}\left(\frac{3{,}4d_f}{1000} + 2{,}25\right)\left(\frac{s}{1000} + 0{,}5\right)\ \text{mm}$$

where

d_f is to be determined from 5.5.3
k_s and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = 0{,}11 k_s\, L_R \text{ cm}^2$$

where

L_R and k_s are as defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.3 and Ch 3,7.5.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also* Ch 3,4.12.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem is to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 0{,}6 k_s L_R \text{ cm}^2$$

where

k_s and L_R are as defined in 1.5.1.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$$t_w = \sqrt{k_s}\,(0{,}06 L_R + 3) \text{ mm within } 0{,}4 L_R \text{ amidships}$$

$$= \sqrt{k_s}\,(0{,}06 L_R + 2) \text{ mm at ends}$$

where

k_s and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floors is to be not less than:

$$t_w = \sqrt{k_s}\,(0{,}03 L_R + 3{,}5) \text{ mm}$$

where

k_s and L_R are as defined in 1.5.1.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

6.5.3 Additionally, the requirements of 4.6 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engineroom.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loading

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the craft are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross-deck structure acts as a watertight bulkhead pipe or cable runs through the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross-deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8*
Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 3.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy submitted for consideration.

■ *Section 9* Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

Section 1
General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_s = higher tensile steel factor

= $235/\sigma_s$

σ_s = specified minimum yield strength of the material, in N/mm^2.

Section 2
Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Steels are to be of suitable grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:
(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:
(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation, calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.21.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designer/builder is to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure,
(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting, the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.1 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details and calculations of the hull attachment.
(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purpose, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load Area**. The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1000 \quad k_s} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1

α = thickness coefficient obtained from Fig. 5.3.1

s = secondary stiffener spacing, in mm

β_p = tyre print coefficient used in Fig. 5.3.1

$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$

s and k_s are as defined in 1.2.

Table 5.3.1 Deck plate thickness calculation

Symbols	Expression
a, s, u, and v as defined in Fig. 5.3.1 n = tyre correction factor as detailed in Table 5.3.2 P_1 = corrected patch load, in tonnes λ = dynamic magnification factor P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print ϕ_1 = patch aspect ratio correction factor ϕ_1 = panel aspect ratio correction factor ϕ_1 = wide patch load factor	$P_1 = \phi_1\, \phi_2\, \phi_3\, \lambda\, P_w$
	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ $v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
	$\phi_2 = 1{,}0$ for $u \leq (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$ for $a \geq u > (a - s)$ $= 0{,}77 \dfrac{a}{u}$ for $u > a$
	$\phi_3 = 1{,}0$ for $v < s$ $= 0{,}6\,(s/v) + 0{,}4$ for $1{,}5 > (v/s) > 1{,}0$ $= 1{,}2\,(s/v)$ for $(v/s) \geq 1{,}5$
	λ = 1,25 for craft operating in G1 = $(1 + 0{,}35n)$ for craft operating in G2 = $(1 + 0{,}42n)$ for craft operating in G3 = $(1 + 0{,}49n)$ for craft operating in G4 = $(1 + 0{,}56n)$ for craft operating in G5 = $(1 + 0{,}70n)$ for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5.

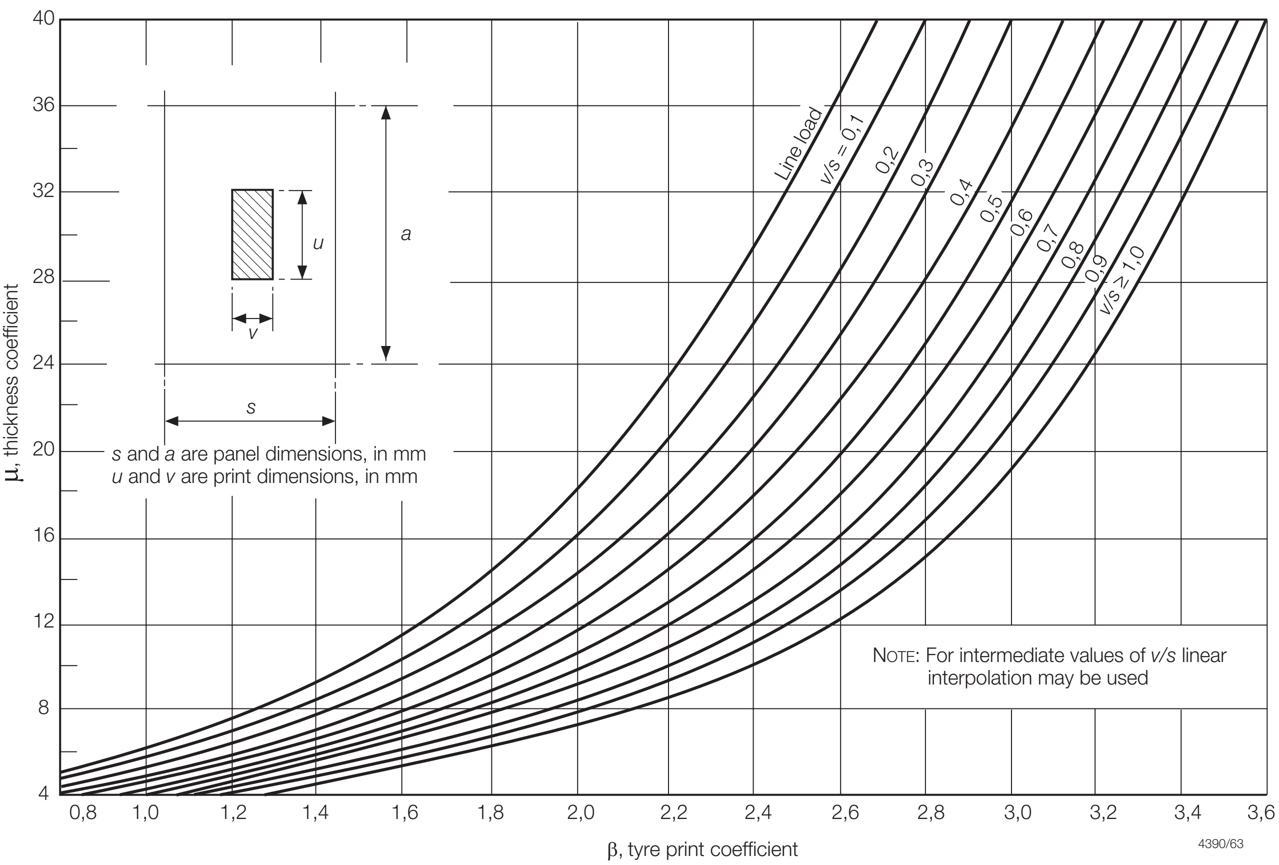


Fig. 5.3.1 Tyre print chart

3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, *n*	Solid rubber tyres correction factor, *n*
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case $d \le l$	Load case $d > l$
Section modulus (Z) (cm^3)	$Z = \left(\dfrac{P\, k_W (3l^2 - d^2)}{24\, l\, f_\sigma\, \sigma_S}\right) \times 10^3 + Z_{dk}$	$Z = \left(\dfrac{k_W\, P\, l^2}{10d\, f_\sigma\, \sigma_S}\right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\dfrac{f_\delta\, P\, k_W (2l^3 - 2d^2\, l + d^3)}{384E\, l}\right) \times 10^5 + I_{dk}$	$I = \left(\dfrac{f_\delta\, k_W\, P\, l^3}{384E\, d}\right) \times 10^5 + I_{dk}$
Web area (A_W) (cm^2)	$A_W = \dfrac{10P\, k_W (m^3 - 2m^2 + 2)}{2f_\tau\, \tau_S} + A_{dk}$ where $m = d/l$	$A_W = \dfrac{k_W\, P\, l}{2d\, f_\tau\, \tau_S} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's Modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_W = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_S = specified minimum yield strength of the material, in N/mm^2
τ_S = shear stress of material, in N/mm^2
= $\dfrac{\sigma_S}{\sqrt{3}}$
Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2.

3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two dimensional grillage model. Copies of calculations are to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* **Bow doors**

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2
A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2
A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser
A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2
a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2
b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in Fig. 5.4.2
c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2
d_{bv} = Vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, as shown in Fig. 5.4.2
h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1
K_s = higher tensile steel factor
= $235/\sigma_s$
l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2
Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1
W_{bv} = mass of the visor door, in tonnes
W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2
σ = bending stress, in N/mm^2
σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$
σ_s = specified minimum yield strength of the material, in N/mm^2
τ = shear stress, in N/mm^2.

4.3.2 **Locking device**. A device that locks a securing device in the closed position.

4.3.3 **Securing device**. A device used to keep the door closed by preventing it from rotating about its hinges.

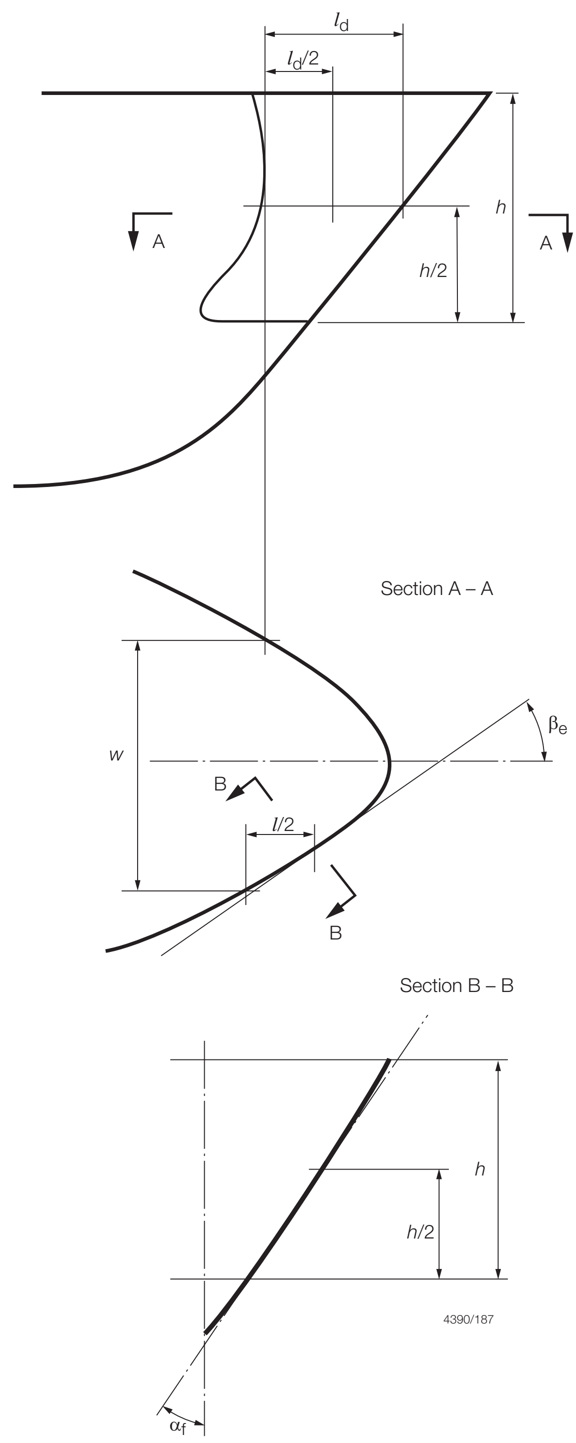


Fig. 5.4.1 Measurement of α_f and β_e

4.3.4 **Side-opening doors**. Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

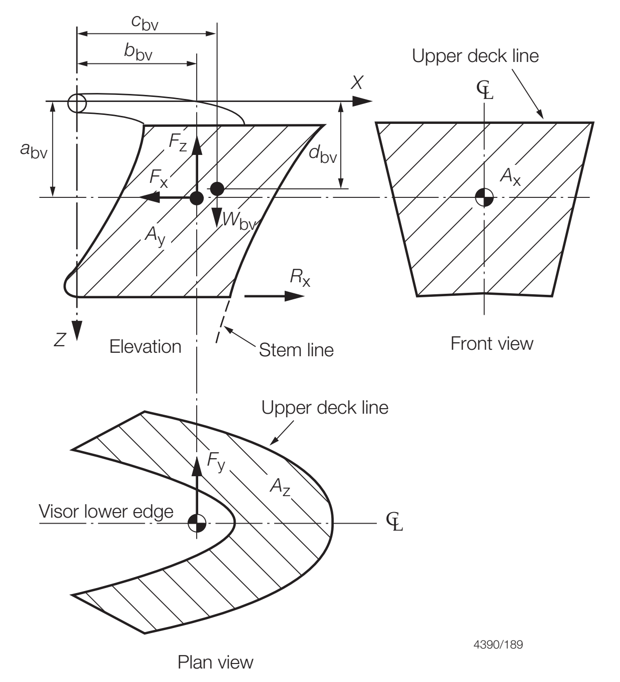


Fig. 5.4.2 Bow visor (upward hinging)

4.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

4.3.6 **Visor doors**. Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $80/k_s$ N/mm^2, $120/k_s$ N/mm^2 and $150/k_s$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2{,}75\lambda_G C_H (0{,}22 + 0{,}15\tan\alpha_f)$$
$$(0{,}4V_{max} \sin\beta_e + 0{,}6L_R^{0{,}5})^2 \quad \text{kN/m}^2$$

where

V_{max} = maximum speed, in knots, as defined in Pt 1, Ch 2, 2.2.10

L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and Group 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and Group 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively:

where

P_e is the external pressure, defined in 4.5.1, with the flare angle α_f, and the entry angle β_e, measured at the point on the bow door
$l_d/2$ aft of the stem line on the plane, and
$h/2$ above the bottom of the door, as shown in Fig. 5.4.1
A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \quad \text{kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1,
F_x and F_z are as defined in 4.5.2.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of 0,45L_R and 10h_2, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between the craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{23,5Q_{bd}}{\sigma_s} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_s are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self-closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_y = 10W_{bv}\,c_{bv} + 0,1(a_{bv}^2 + b_{bv}^2)^{0,5}\ (F_x^2 + F_z^2)^{0,5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1, F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z
Case 2 0,7F_y acting on each side separately together with 0,7F_x and 0,7F_z.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.
Case 2 0,7F_x and 0,7F_z acting on both doors and 0,7F_y acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are generally to give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

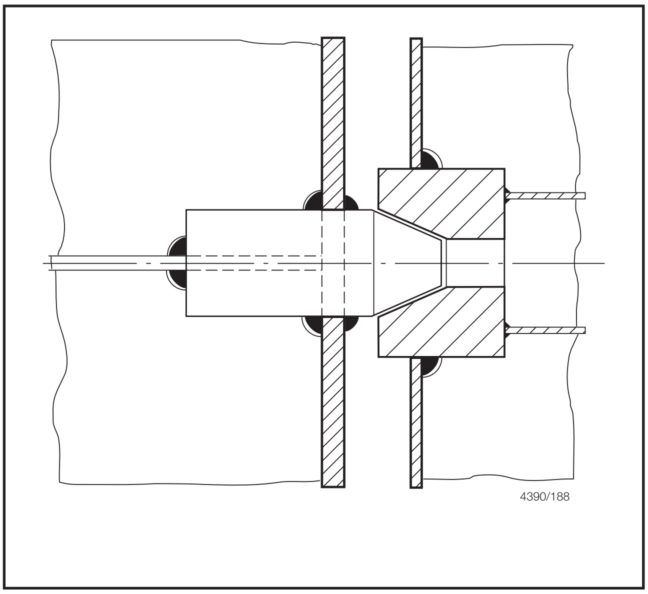
where

W_{bv}, A_x, d_{bv} and a_{bv} as defined in 4.3.1.

4.8.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z – 10W_{bv}), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For side-opening doors, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.



4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and
(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, and arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damage.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance is to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings;
(b) service conditions, e.g. service area restrictions and acceptable clearances for supports;
(c) maintenance and function testing;
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

Section 6
Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements of the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha\, s}{1000 \quad k_s}$$

α = thickness coefficient obtained from Fig. 5.3.1
β_p = tyre print coefficient used in Fig. 5.3.1
$= \log_{10}\left(\frac{P_1\, k_s^2}{s^2} \times 10^7\right)$

where
s and k_S are defined in 1.2.

The plating is to be designed for the emergency landing case taking

$P_1 = 2{,}5\, \phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w$ tonnes

where
ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1
f = 1,15 for landing decks over manned spaces, e.g. deckhouses, bridges, control rooms, etc.
= 1,0 elsewhere
P_h = the maximum all up weight of the helicopter, in tonnes
P_w = landing load on the tyre print, in tonnes;
For helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels.
For helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main undercarriage wheels in proportion to the static loads they carry.
For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as $1/6P_h$ for each of the two forward contact points and $1/3P_h$ for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 5.3.1.

γ = a location factor given in Table 5.6.1

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 mm x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from Fig. 5.3.1.

Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder:	
(a) within 0,4L_R amidships	0,71 Values for intermediate locations are to be
(b) at the F.P. or A.P.	0,6 determined by interpolation
Elsewhere	0,6

6.4 Deck stiffening and supporting structure

6.4.1 The helicopter deck stiffening and the supporting structure are to be designed for the load cases given in Table 5.6.2, with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

■ *Section 7* Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

7.2 Shell plating

7.2.1 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.2.2 In general, all welded seams and butts in way of the main ice belt are to be dressed smooth.

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL, in kN/m^2	Helicopter patch load *see* Note 2	Self weight	Horizontal load *see* Note 2
(1) Overall distributed loading	2	–	–	–
(2) Helicopter emergency landing	0,5	2,5$P_w f$	W_h	0,5P_h
(3) Normal Usage	0,5	1,5P_w	W_h	0,5P_h + 0,5W_h
Symbols				
P_h, P_w and f are as defined in 6.3.1. *UDL* = Uniformly distributed vertical load over entire landing area W_h = structural self-weight of helicopter platform, in tonnes				
NOTES 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

Section

Section 1
General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of steel construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the craft, in metres

B = moulded breadth of craft, *see* Pt 3, Ch 1,6.2.1, in metres (to be taken as the breadth of a single hull for multi-hull craft)

l = overall span length of stiffening member, in metres

l_e = effective span length of stiffening member, in metres

p = design pressure as appropriately given in Part 3, in kN/m^2

s = spacing of stiffener, in mm

t_p = thickness of plating, in mm

σ_s = specified minimum yield strength of the material, in N/mm^2

β = panel aspect ratio correction, *see* Ch 3,1.15

$\tau_s = \dfrac{\sigma_s}{\sqrt{3}}$

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

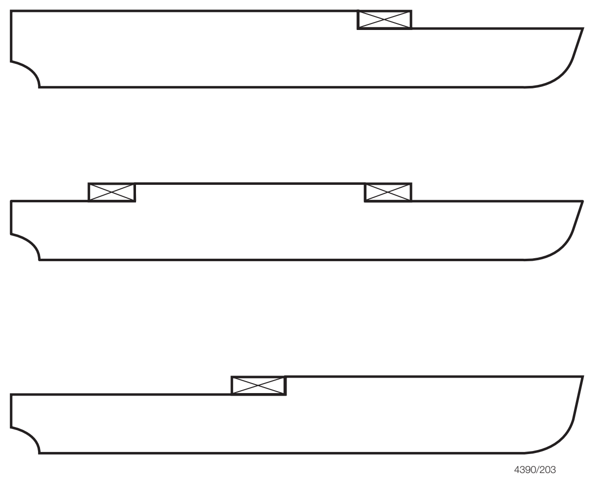


Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within $0,4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0,4L_R$ part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding $0,1B$ m or a breadth exceeding $0,05B$ m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma\, b_o$).

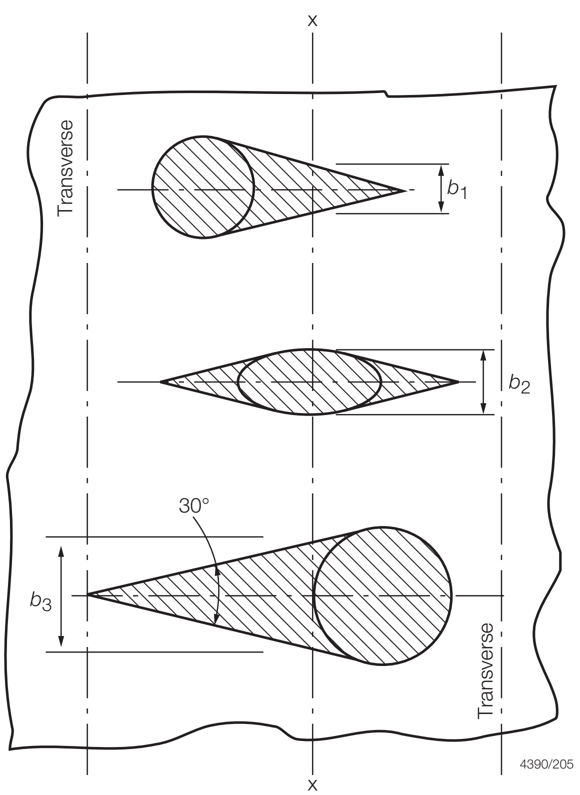
where

B_o = breadth of craft, in metres, at section considered

$\Sigma\, b_o$ = sum of breadths, in metres, of deductible openings

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than 3,0 per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.

(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.

(c) Details of the calculated lightweight and its distribution.

(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

Section 2
Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 50 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The contribution that higher tensile steel makes to the global strength is based upon the strain in that material in relation to the allowable strain in mild steel. Therefore, the maximum permissible hull vertical bending stress, σ_p, for the design analysis is not to be taken greater than that determined from the following:

$$\sigma_{p\,(HTS)} = \sigma_{p\,(MS)}\ \frac{\overline{y}_{(HTS)}}{\overline{y}_{(MS)}}$$

where

σ_p is as defined in 2.2.3

$\overline{y}_{(HTS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective higher tensile steel element contributing to global longitudinal strength

$\overline{y}_{(MS)}$ = the maximum distance, in metres, above or below the neutral axis of the hull cross-section to any effective mild steel element contributing to global longitudinal strength.

2.2.3 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P \text{ and}$$
$$\sigma_d < \sigma_P$$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2 and is not to be taken greater than that determined from 2.2.2

= $f_{\sigma gH}$, σ_s or the value determined from 2.2.2, whichever is the lesser

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_s is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \dfrac{M_R}{1000Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \dfrac{M_R}{1000Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \dfrac{p_s\, s\, l_e^2}{12Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34P_t\left(\dfrac{\beta\, s}{t_p}\right)^2 \times 10^{-3}$

Symbols and definitions

M_R = design longitudinal midship bending moment, in kNm, given in Pt 5, Ch 5,5
p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3
P_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4
Z_d = actual section modulus at deck, in m^3
Z_k = actual section modulus at keel, in m^3
Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3
s, l_e, β and t_p are as defined in 1.2.

2.2.4 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$$\sigma_k < \sigma_P$$
$$\sigma_d < \sigma_P$$

where

σ_P is as defined in 2.2.3
σ_k and σ_d are given in Table 6.2.1
L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

2.3 Minimum hull section modulus

2.3.1 For patrol craft in Service Group G6, the hull midship modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$Z_{min} = \eta_{HTS} L_f L_R^2 B_{WL} (C_b + 0,7) \times 10^{-6}$ m^3

where

η_{HTS} is as defined in Ch 2,2.4.3
L_R and C_b are as given in Pt 5, Ch 2,2.2.2
C_b to be taken not less than 0,6
L_f is as given in Pt 5, Ch 5,2.2.2
B_{WL} = maximum breadth at the design waterline, in metres.

2.4 Shear strength

2.4.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \le \tau_p$$

where

Q_R = design hull shear force at any section along the Rule length, L_R, in kN determined from Pt 5, Ch 5,5
A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1
τ_p = maximum permissible mean shear stress, in N/mm^2
= $f_{\tau gH}\ \tau_s$
$f_{\tau gH}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7
τ_s is as defined in 1.2.1.

2.5 Torsional strength

2.5.1 Torsional stresses are typically small for mono hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.5.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.6 Superstructures global strength

2.6.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4*L* amidships and where:

$l_1 > b_1 + 3h_1$

where

l_1 = length of first tier, in metres
b_1 = breadth of first tier, in metres
h_1 = 'tween deck height of first tier, in metres.

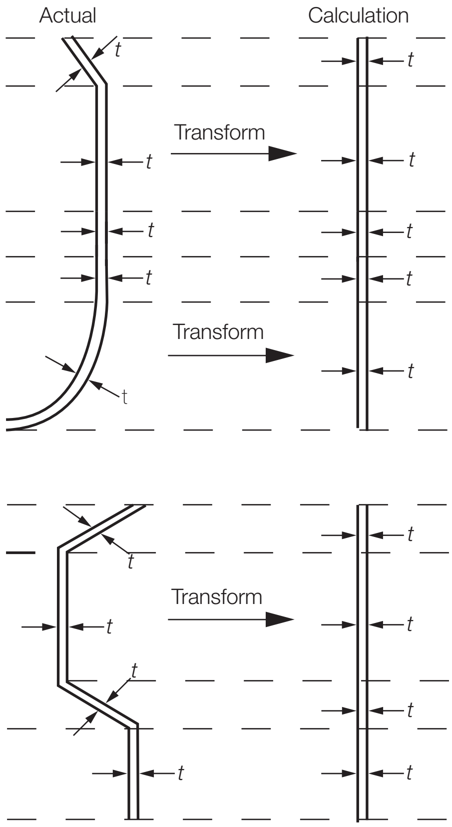


Fig 6.2.1 Effective shear area

2.6.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\,[(\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5,8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma]\,f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$
$f(\lambda, N = 2) = 0,90\lambda^3 - 2,17\lambda^2 + 1,73\lambda + 0,50$

and

N = 1 if $l_2 < 0,7l_1$
= 2 if $l_2 \ge 0,7l_1$

$\lambda = \dfrac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \dfrac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \dfrac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for $N = 1$
$= \dfrac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = as defined in 1.2.1, in metres
l_1, b_1, h_1 = as defined in 2.5.1, in metres
l_2 = length of second tier, in metres.

2.6.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm

Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3

η_s = as defined in 2.6.2.

2.6.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.6.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s > \left(1 + \frac{Z_0\, h}{I_{100}}\right)^{-1}$$

where

η_s = as defined in 2.6.2

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

■ *Section 3* Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:

(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.

(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\, \sigma_s$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\, \tau_s$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2 f_{\sigma eg}\, \sigma_s$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} σ_d, and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2 $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7 σ_s and τ_s are defined in 1.2		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR} \dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB} \dfrac{M_B}{nZ} 10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT} \dfrac{3x_H M_T}{n\,(n+1)\, s_p Z} 10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB} \dfrac{5Q_T}{n A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT} \dfrac{60 M_T}{n\,(n+1)\, s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT} \dfrac{46\kappa\, x_H^2 M_T}{n\,(n^2+1)\, s_p^2 I_y} 10^3$
Symbols and definitions	
Q_T = vertical shear force, in kN, as determined from Pt 5, Ch 5,5 M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5 M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5 n = total number of transverse primary stiffeners or bulkheads A_W = stiffener web area, cm^2 Z = primary stiffeners section modulus, in cm^3 s_p = stiffener spacing, in metres I_y = moment of inertia of stiffener, cm^4 x_H = transverse distance between the centre of the two hulls, in metres κ = t_f, for symmetrical I-section, in mm = $b_b\, h/(b_b + h)$, for constant thickness box sections, in mm σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2 σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2 t_f = face plate thickness, in mm b_b = breadth of box section, in mm h_b = height of box section, in mm f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.	

Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross-deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Section

Section 1 General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of steel construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

Section 2 Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio, f_δ, in consistent units.

Table 7.2.1 Limiting deflection ratio

Item	Deflection ratio, f_δ
Bottom structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Side structure:	
• secondary stiffening	800
• primary girders and web frames	1000
Main/strength deck structures:	
• secondary stiffening	1000
• primary girders and web frames	1250
• hatch covers	1250
Superstructures/deckhouses stiffeners:	
(a) Generally: • secondary	600
• primary	750
(b) Coachroof: • secondary	800
• primary	1000
(c) House top: • secondary	600
• primary	600
Lower/inner decks and house top subject to personnel loading:	
• secondary members	800
• primary members	1000
Deep tank stiffeners:	
• secondary members	1000
• primary members	1250
Watertight bulkhead stiffeners:	
• secondary members	600
• primary members	750
Multi-hull cross-deck stiffeners:	
• secondary members	800
• primary members	1000
Vehicle deck stiffeners:	
• secondary members	1000
• primary members	1250
Helicopter/flight decks stiffeners:	
• secondary members	1000
• primary members	1250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

Section 3 Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the yield stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x{}^2 + \sigma_y{}^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction

σ_y = direct stress in the y direction

τ = shear stress in the xy plane

Table 7.3.1 Limiting stress coefficients for local loading (*see continuation*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Side shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(c) Keel		0,75	—	—
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75
Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
Bow doors:				
(a) Plating		0,65	—	—
(b) Secondary stiffening		0,51	0,433	—
(c) Primary stiffening		0,51	0,34	0,64
Main/strength deck plating and stiffeners:				
(a) Plating		0,75	—	—
(b) Secondary stiffening		0,65	0,65	—
(c) Primary girders and web frame		0,65	0,65	0,75
(d) Hatch covers		0,55	0,55	0,64
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	—	—
	• stiffening	0,60	0,60	—
(b) Deckhouse front upper tiers:	• plating	0,75	—	—
	• stiffening	0,65	0,65	—
(c) Deckhouse aft and sides:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(d) Coachroof:	• plating	0,65	—	—
	• stiffening	0,65	0,65	—
(e) House top:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(f) Lower/inner decks and house top subject to personnel loading:				
	• plating	0,75	—	—
	• stiffening	0,60	0,60	—

Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_{σ}	Shear f_{τ}	Equivalent f_e
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	—
(c) Structure supporting watertight doors		0,80	0,80	
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,6	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,6
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,00	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,70	0,75

Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ or $\Delta \leq 0,04(L_R\, B)^{1,5}$	0,80 η_{HTS}	0,80 η_{HTS}	0,825 η_{HTS}	0,80 η_{HTS}	0,80 η_{HTS}	0,825 η_{HTS}
$\Gamma < 3,0$ and $\Delta > 0,04(L_R\, B)^{1,5}$	0,72 η_{HTS}	0,72 η_{HTS}	0,75 η_{HTS}	0,72 η_{HTS}	0,72 η_{HTS}	0,75 η_{HTS}

NOTES
$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Δ is the displacement as defined in Pt 5, Ch 2,2
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
L_R and B are as defined in Pt 3, Ch 1,6.2
η_{HTS} is as defined in Ch 2,2.4.3

■ *Section 4* Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owners extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

t_p = thickness of plating, in mm
A_R = panel aspect ratio
$= \dfrac{a}{b}$
a = panel length, i.e. parallel to direction of compressive stress being considered, in mm
b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm
S_p = span of primary members, in metres
σ_o = specified minimum yield strength of the material, in N/mm^2
σ_e = elastic compressive buckling stress, in N/mm^2
σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2
τ_o = specified minimum yield shear stress of the material, in N/mm^2
$= \dfrac{\sigma_o}{\sqrt{3}}$ N/mm^2
E = modulus of elasticity of material in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2
b_{eb} = lesser of $1,9 t_p \sqrt{\dfrac{E}{\sigma_o}}$ or $0,8b$ mm
A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}
s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)
l = length of longer edge of plate panel, in metres.
S = spacing of primary member, in metres (measured in direction of compression).

4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d) and (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels with plating thicknesses below 8 mm the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

or σ_c as derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_o are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,

$\sigma_d > \sigma_e$

(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \le \frac{\sigma_o}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \le \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.

(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

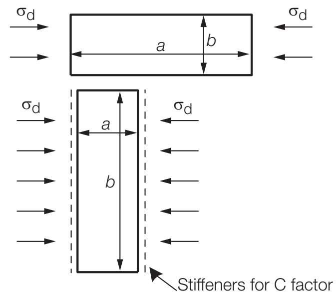
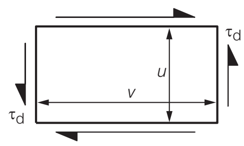
$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling.

λ_σ is the buckling factor of safety = 1,25.

Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note 1	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi\, E\left(\frac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0{,}9C\,\varphi\left(\frac{b}{a} + \frac{a}{b}\right)^2 E\left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E\left(\frac{t_p}{u}\right)^2$ *See* Note 2	

NOTES

1. The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_o}{2}$$

σ_c is defined in 4.2.1
σ_o is defined in 4.2.1

$$\tau_c = \tau_e \text{ when } \tau_e < \frac{\tau_o}{2}$$

$$= \tau_o\left(1 - \frac{\tau_o}{4\tau_e}\right) \text{ when } \tau_e \geq \frac{\tau_o}{2}$$

τ_c is defined in 4.2.1
τ_o is defined in 4.2.1

2. *u* is to be the minimum dimension

Symbols and definitions

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and *b* are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress
μ = $\frac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_o} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_o\left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

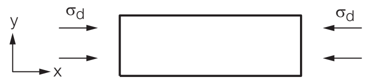
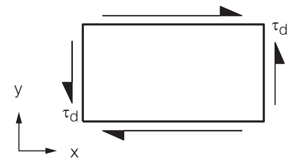
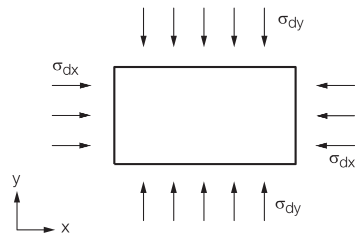
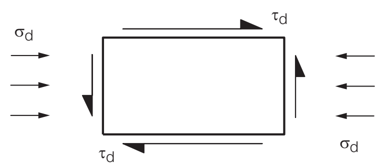
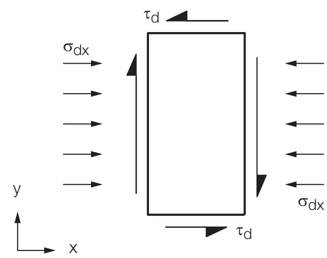
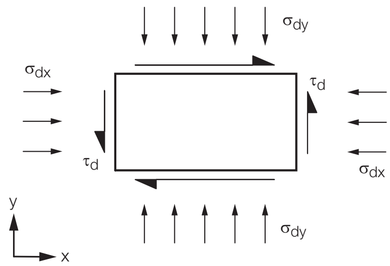
$$\sigma_u = \frac{1{,}77\sigma_o A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and *s* are defined in 4.2.1.
t_p, *E* and σ_o are defined in 4.2.1.

Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_d}{\sigma_c} \le \frac{1}{\lambda_\sigma}$	
(b)	shear loads	$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for A_R = 1,0 $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1,0$ for other aspect ratios, i.e. $A_R \ne 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ where *G* is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1 + 0,6A_R}{1,6}\right)\left(\frac{\sigma_d}{\sigma_c}\right) + \left(\frac{\tau_d}{\tau_c}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$\frac{0,625\left(1 + \frac{0,6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0.625\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} + \frac{\left(\frac{\tau_d}{\tau_c}\right)^2}{1 - \left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

σ_d = design compressive stress, *see* 4.1.3
σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
σ_{dx} = design compressive stress in x direction
σ_{dy} = design compressive stress in the y direction
σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
τ_d = design shear stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5

Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note 1
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \dfrac{I_a}{A_{te}\, l_e^2}$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \dfrac{0{,}001 E\, I_w}{I_p\, l_e^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385 E \dfrac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E \left(\dfrac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E \left(\dfrac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end is pinned and the other end is fixed
= 4 where both ends are fixed
E = Young's Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note 2
t_p and σ_o are given in 4.2.1
A_{te} and b_{eb} are given in 4.2.1
I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$$= \frac{d_w\, t_w^3}{3}\, 10^{-4} \quad \text{for flat bars}$$

$$= \frac{1}{3}\left[d_w\, t_w^3 + b_f\, t_f^3\left(1 - \frac{0{,}63\, t_f}{b_f}\right)\right]10^{-4} \quad \text{for built up profiles, rolled angles and bulb plates}$$

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$$= \frac{d_w^3\, t_w}{3}\, 10^{-4} \quad \text{for flat bars}$$

$$= \left(\frac{d_w^3\, t_w}{3} + d_w^2\, b_f\, t_f\right)10^{-4} \quad \text{for built up profiles, rolled angles and bulb plates}$$

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$$= \frac{d_w^3\, t_w^3}{36}\, 10^{-6} \quad \text{for flat bars}$$

$$= \frac{t_f\, b_f^3\, d_w^2}{12}\, 10^{-6} \quad \text{for 'Tee' profiles}$$

$$= \frac{b_f^3\, d_w^2}{12\,(b_f + d_w)^2}\left(t_f\,(b_f^2 + 2b_f\, d_w + 4d_w^2) + 3t_w\, b_f\, d_w\right)10^{-6} \quad \text{for '}L\text{' profiles, rolled angles and bulb plates}$$

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p\, E\, t_p^3}{3b\left(1 + \dfrac{1{,}33 k_p\, d_w\, t_p^3}{b\, t_w^3}\right)}$$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1
η_p = $\dfrac{\sigma_d}{\sigma_{ep}}$
σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2\, m^2$ to $m^2\,(m+1)^2$
m	1	2	3	4	5	6	m

$$K = \frac{1{,}03 C S^4}{E\, I_w}\, 10^4$$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1.

NOTES
1. The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_o}{2}$$

$$= \sigma_o \left(1 - \frac{\sigma_o}{4\sigma_e}\right) \text{when } \sigma_e \geq \frac{\sigma_o}{2}$$

2. For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\, t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3
t is the plating thickness, in mm
A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3
τ_d is the design shear stress
λ_τ is given in Table 7.4.4.

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_τ
Bottom shell plating	1,0	—
Inner bottom plating	1,0	—
Deck plating	1,0	—
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	—
Longitudinal secondary stiffeners	1,1 (1)	—
Girder and floor web plating subject to local loads	1,1	1,2

NOTES
1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \geq 1$$

where

$K_s = 4{,}5 \left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2 - 1}{N^2}\right)\left(\frac{\omega}{1 + \omega}\right)^r\right)$

N = number of subpanels

$= \frac{1000 S_p}{s}$

$\omega = \frac{10 I_{se}}{l\, t^3}$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width $s/2$

$r = 1 - 0{,}75 \left(\frac{s}{1000l}\right)$

s, l, E and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

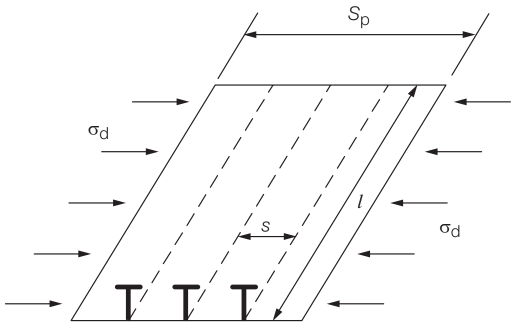


Fig. 7.4.1 Shear buckling of stiffened panels

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note 2 in Table 7.4.1.

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see* 4.7.2

σ_d is the design compressive stress, *see also* 4.5 and 4.1.3

λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1, Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$$\sigma_{c(w)} > \sigma_{c(t)}$$
$$\sigma_{c(f)} > \sigma_{c(t)}$$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$$\sigma_{c(a)} > \sigma_{c(t)}$$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

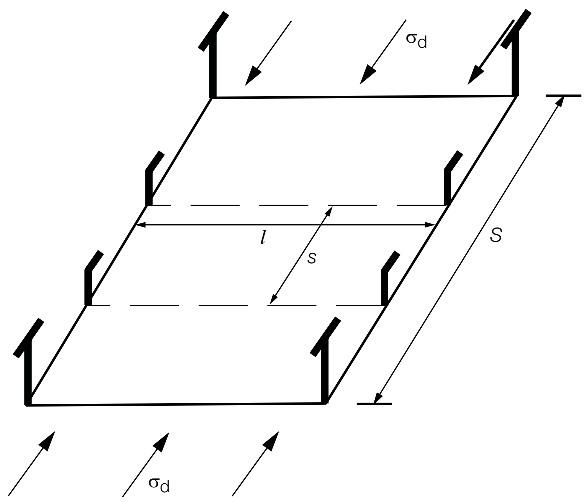


Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

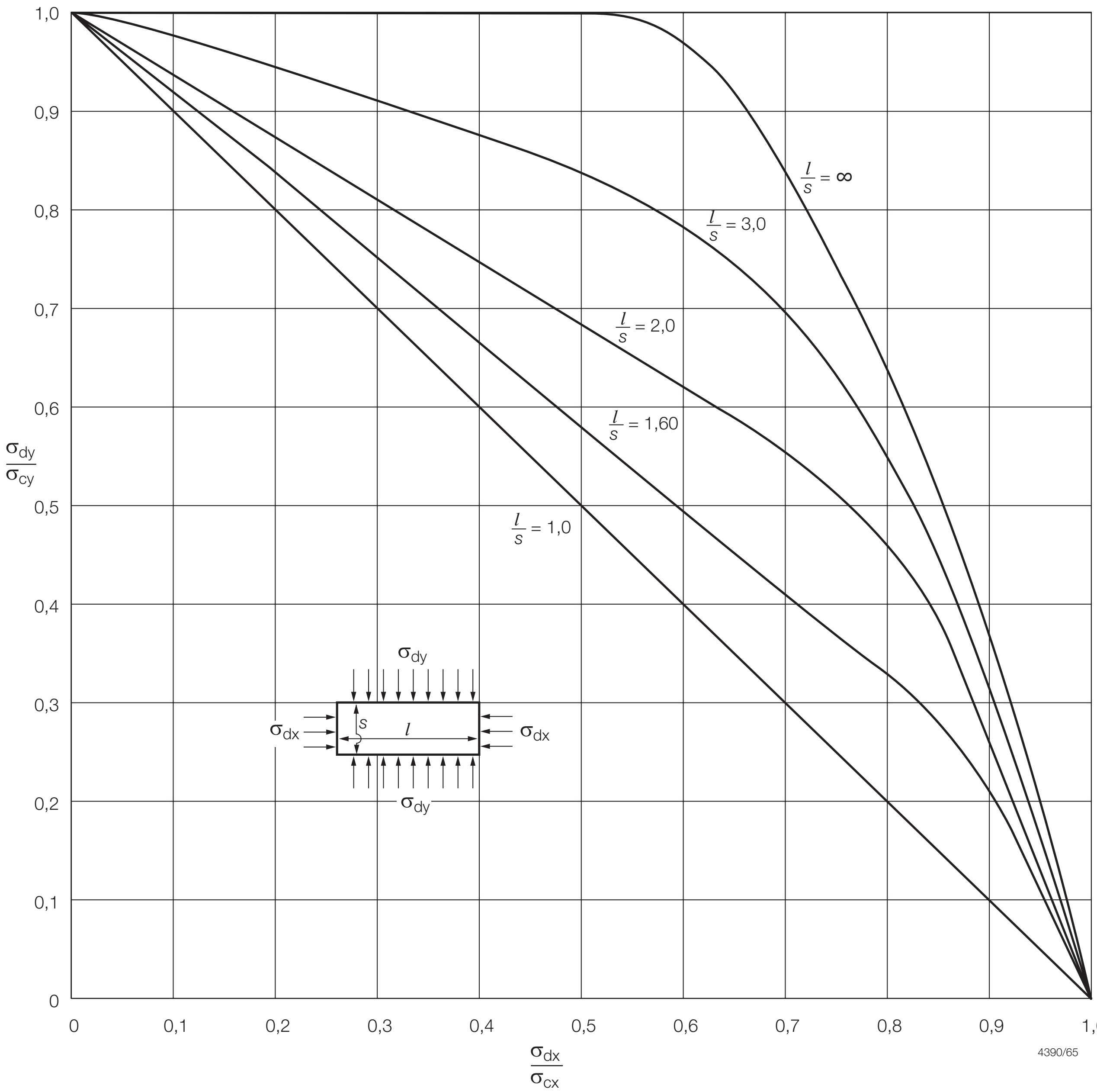


Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, *s*, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\, s\, (4N_L{}^2 - 1)((N_L{}^2 - 1)^2 - 2\,(N_L{}^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L{}^2 + 1 - \kappa)\,\Pi^4\, E} \text{ mm}^4$$

where

$$D = \frac{E\, t_p{}^3}{12\,(1 - \upsilon^2)}$$

$\kappa = A_R{}^2\, \Pi^2$

A_R = plate panel aspect ratio

$$= \frac{s}{1000l}$$

$$\Pi = \frac{S}{l}$$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, *l* and *S* are defined in 4.2.1 and shown in Fig. 7.4.2.

t_p and *E* are defined in 4.2.1.

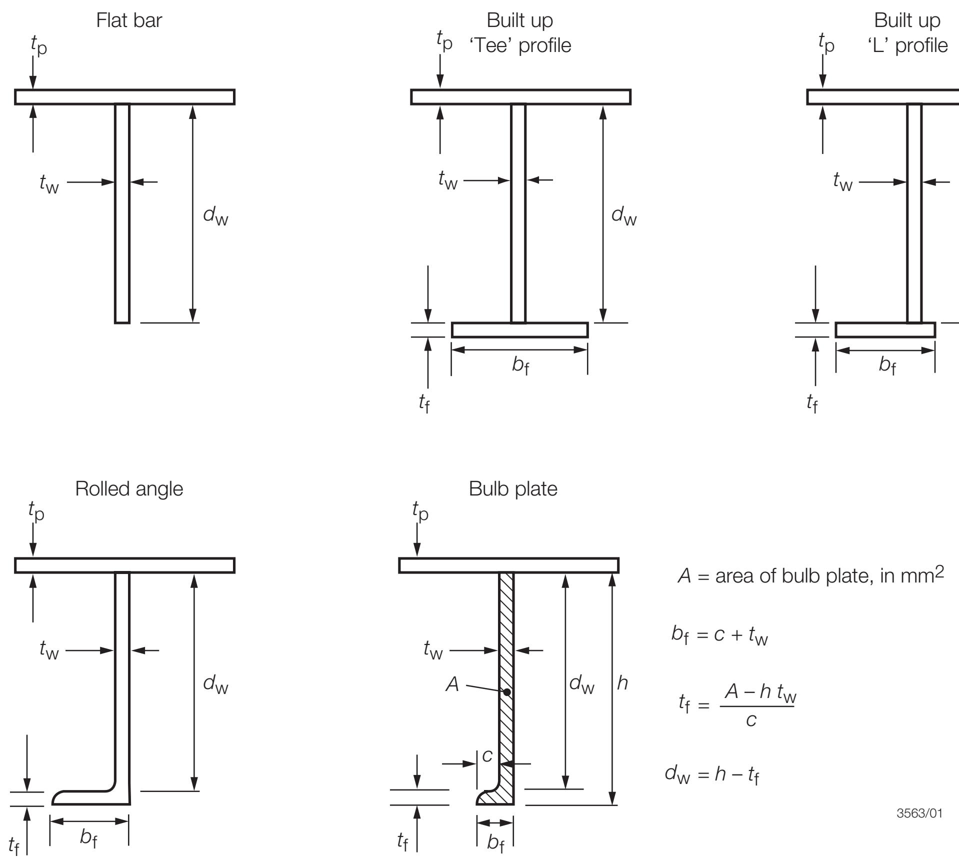


Fig. 7.4.4 Dimensions of longitudinals

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35 S_p^4 \, I_s}{l^3 \, s} \times 10^3 \quad \text{cm}^4$$

S_p and s are as defined in 4.2.1, *see also* Fig. 7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep} \, A_{te} \, l_e^2}{0{,}001 E}$$

where

$$\sigma_{ep} = 1{,}2\sigma_d \ \text{N/mm}^2 \text{ for } \sigma_{e(a)} < \frac{\sigma_o}{2}$$

$$= \frac{\sigma_o^2}{4\,(\sigma_o - 1{,}2\sigma_d)} \text{ for } \sigma_{e(a)} \geq \frac{\sigma_o}{2}$$

σ_d is design stress, in N/mm^2

σ_o and A_{te} are as defined in 4.2.1

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1.

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and Note 1 in Table 7.4.1.

$$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{d_w}{1000\, l_p}\right)^2\right) E \left(\frac{t_w}{d_w}\right)^2 \quad \text{N/mm}^2$$

where

d_w = web height, in mm

t_w = web thickness, in mm

l_p = unsupported length of web, in metres

E is defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

Section 5 Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544 \frac{t_p}{ab} \sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045} \text{ Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi L_b^2} \sqrt{\frac{EI}{m\left(1 + \dfrac{\pi^2 EI}{L_b^2 GA}\right)}} \text{ Hz}$$

where

EI = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \dfrac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi t_p}{1000 a b} \sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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Part 7
Hull Construction in Aluminium
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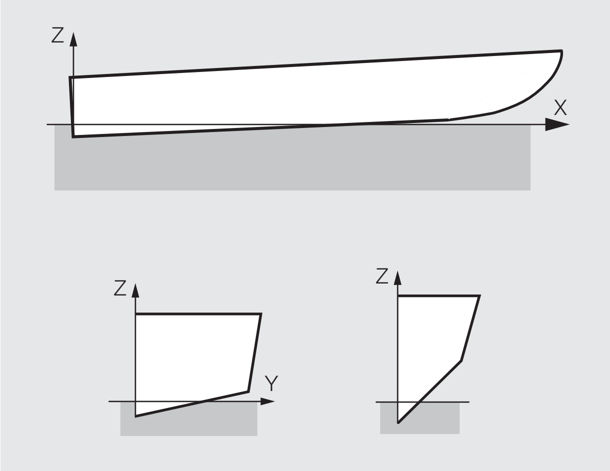
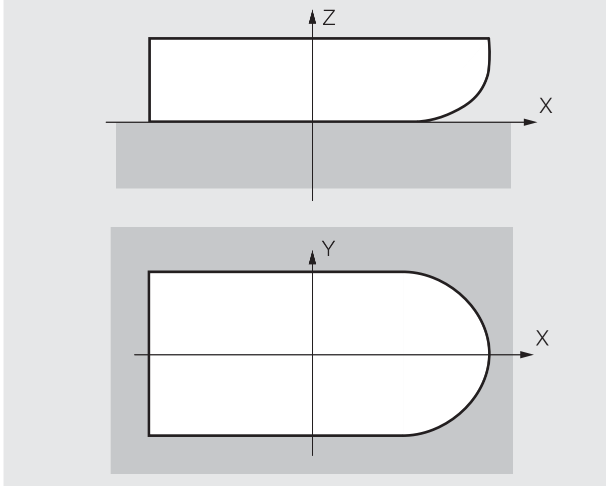
Lloyd's Register
LIFE MATTERS

DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

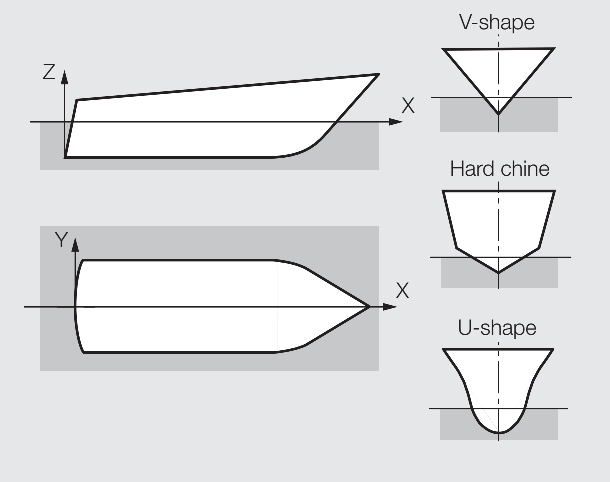
PLANING CRAFT



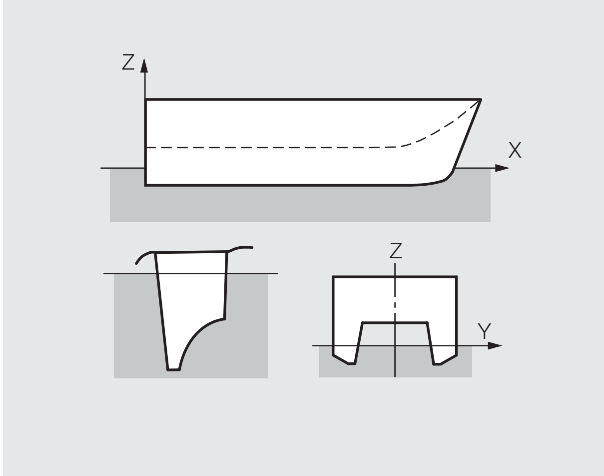
HOVERCRAFT



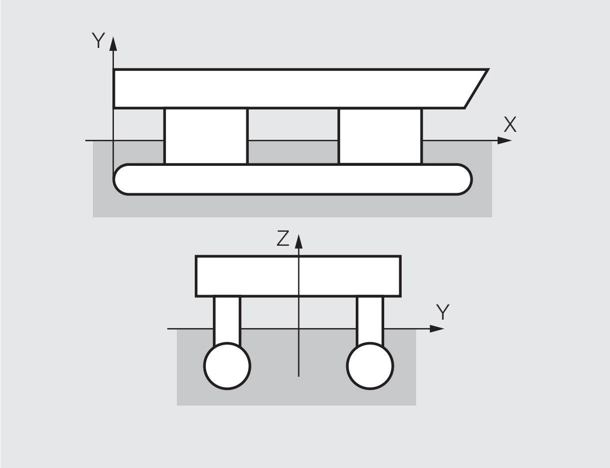
DISPLACEMENT CRAFT



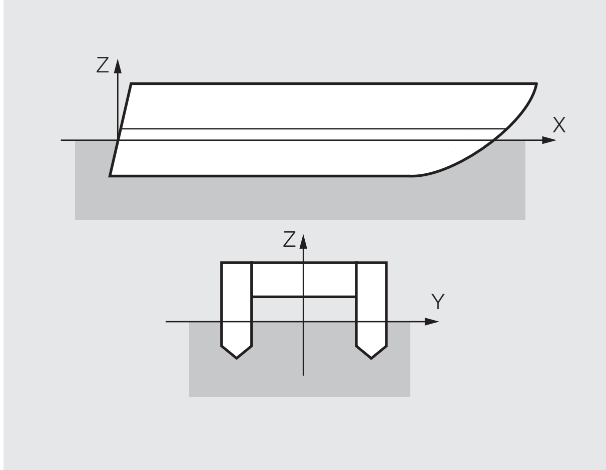
SURFACE EFFECT SHIP



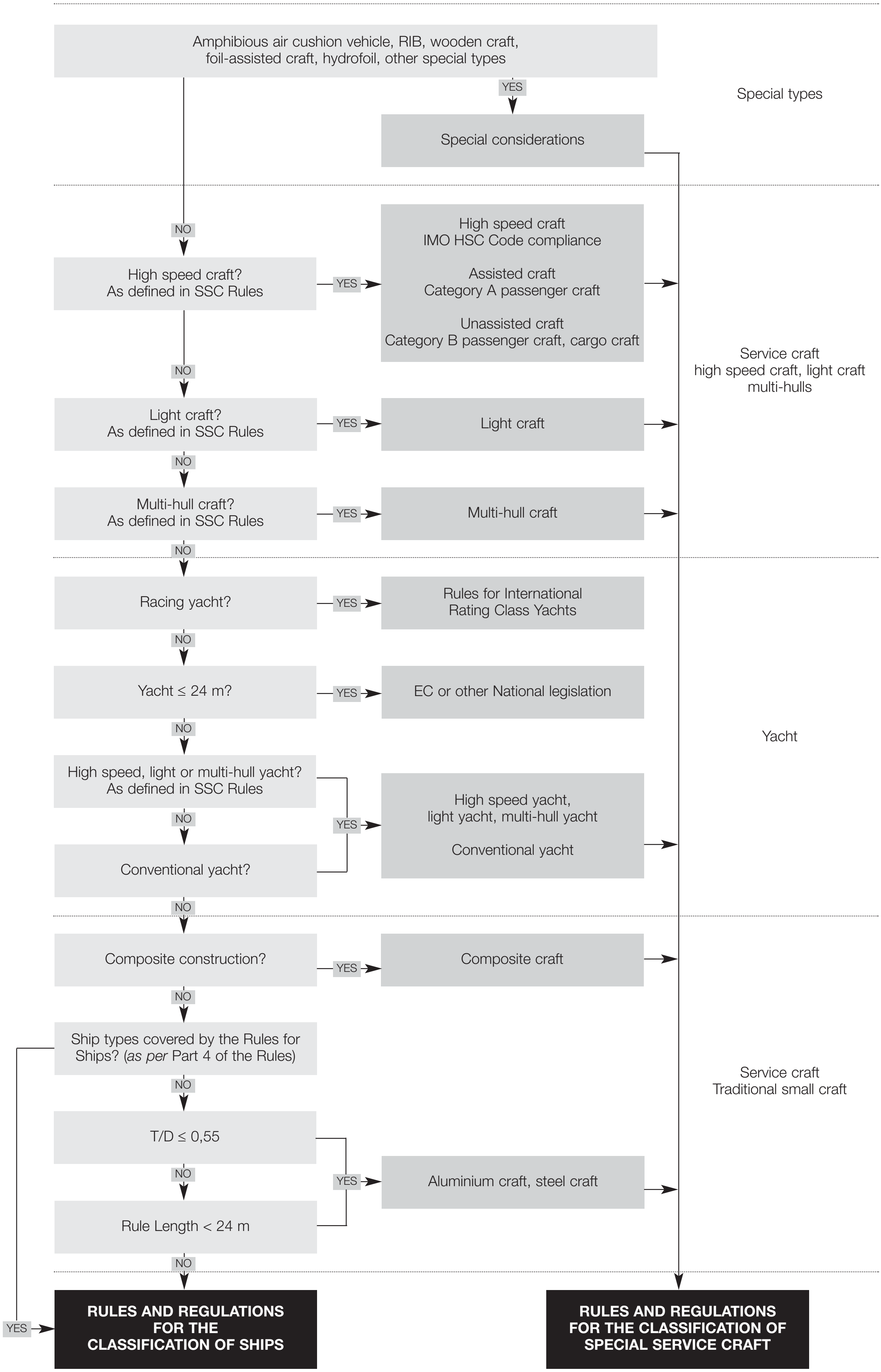
SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN



DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section 1 Application

1.1 General

1.1.1 The Rules apply to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for aluminium craft of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt, regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2 General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing craft types.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Hatch cover construction.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable).
- Ice strengthening.
- Welding schedule.
- Hull penetration plans.
- Support structure for masts, derrick posts or cranes.
- Bilge keels showing material grades, welded connections and detail design.

2.4.2 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted:

- Equipment Number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section modulus.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Novel features

2.5.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.6 Enhanced scantlings

2.6.1 Where the Owner decides to increase the scantling of the bottom shell, side shell and deck plating of a newbuilding, then the craft will be eligible to be assigned the description note **ES**, *see* Pt 1, Ch 2,3.12. For example, the descriptive note **ES+1** would indicate that an extra 1 mm of aluminium has been fitted to bottom shell, side shell and deck plating.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 of the Rules are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration (other than local stiffened flat panels, *see* Ch 7,5), docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of aluminium craft using the metal inert gas (MIG) and tungsten inert gas (TIG) welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and also to comply with any local or National Authority requirements.

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in 1.6.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct craft to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by sub-contractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with 1.5.2, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems, will vary considerably depending on the size and type of craft and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is required to implement a documented Quality Control System which controls the following activities:

- (i) Receipt storage and issue of materials, equipment, etc.
- (ii) Fabrication environment.
- (iii) Weld procedures and welder performance.
- (iv) Production fabrication.
- (v) Inspection of production processes.
- (vi) Installation of machinery and essential systems.
- (vii) Fitting-out.
- (viii) Tests and trials.
- (ix) Drawings and document control.
- (x) Records.

1.6.3 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.4 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously how each of the activities specified in 1.6.2(c) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.5 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The craft is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 Aluminium is to be stored in dry places, clear of the ground. Contact with other metals and with materials such as cement and damp timber is to be avoided. Aluminium sheet and plate are to be stacked, in general, on end in racks to avoid distortion.

1.8.3 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.4 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.5 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record on receipt the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during periodical survey.

1.10.2 Production faults are to be discussed with the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 Inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and to facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable deckhead and shipside linings, cabin soles, etc.

1.11.5 During inspections all deviations are to be dealt with in accordance with 1.6.4.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the certification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.4.

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

■ *Section 2* Materials

2.1 General

2.1.1 The materials used in the construction of the craft are to be manufactured and tested in accordance with the appropriate requirements of Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.2 As an alternative to 2.1.1, materials may be accepted for specific applications, provided they are manufactured and tested in accordance with the requirements of national or proprietary specifications which give reasonable equivalence to the requirements of the Rules for Materials. Additional tests may be required to prove that the materials are suitable for the intended purpose in respect of mechanical properties, weldability and corrosion resistance.

2.1.3 All materials are to be manufactured at works which have been approved by LR for the type and, where appropriate, grade of aluminium which is being supplied and for the relevant aluminium production and processing route.

2.2 Aluminium alloy plates, bars and sections

2.2.1 Materials are, in general, to be limited to the supply conditions detailed in Ch 8,1.6 of the Rules for Materials. Other supply conditions may be accepted but, as materials in a condition other than annealed are subject to a loss of mechanical strength in the vicinity of welded joints, the strength used in design calculations are to be as given in 2.4.

2.2.2 For applications where the material will be subject to high local stresses, it is recommended that the scantlings, when using higher strength materials, be determined on the basis of the mechanical properties of the material in the as-welded annealed condition.

2.3 Aluminium alloy castings

2.3.1 All structural castings are to be manufactured and tested in accordance with the appropriate requirements of Ch 8,3 of the Rules for Materials.

2.4 Mechanical properties for design

2.4.1 The minimum tensile strength properties of aluminium alloys approved for structural use are given in Ch 13,8.3.2 of the Rules for Materials. Other alloys and conditions of temper may be accepted in accordance with 2.1.3.

2.4.2 In general, for welded structure, the maximum value for the strength of the material, σ_a, to be used in the scantling derivation is that of the aluminium alloy in the welded condition, where σ_a is defined as the 0,2 per cent butt welded proof stress or 70 per cent of the ultimate strength of the material in the welded condition in N/mm^2, whichever is the lesser.

2.4.3 The tensile modulus of elasticity to be used in scantling calculations is 69 x 10^3 N/mm^2 for all aluminium alloy materials.

2.4.4 The type of material, specification to which it is manufactured (including grade and temper) and minimum guaranteed mechanical properties are to be indicated on the construction drawings.

2.5 Cathodic protection

2.5.1 The potential of the aluminium-magnesium (5000 Series) and the aluminium-magnesium-silicon (6000 Series) alloys is generally in the range –0,7 to –0,9 Volts with reference to a silver/silver chloride sea-water reference electrode. A negative potential swing of at least 0,1 Volts from the corrosion potential is necessary to provide cathodic protection in sea-water (i.e. –0,8 to –1,0 Volts). The limit of negative potential is, however, not to exceed –1,1 Volts with reference to a silver/silver chloride sea-water reference electrode. Zinc or aluminium-zinc-indium or aluminium-zinc-tin anodes may be used for cathodic protection but aluminium anodes containing mercury are not acceptable.

2.5.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.6 Paints and coatings

2.6.1 The hull, deck, deckhouse and superstructure and other structure which is exposed to the marine environment is to be protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section. Internal structure need not in general be coated provided that they are built of aluminium alloy grades shown in Chapter 8 of the Rules for Materials.

2.6.2 Aluminium alloy is to be suitably cleaned, cleared of oxide and degreased before the application of any protective coating.

2.6.3 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification. The paint or coating is to be compatible with any previously applied primer.

2.6.4 Paints containing lead, mercury or copper are not to be used in conjunction with aluminium alloys.

2.6.5 Paints, varnishes and similar preparations having a nitro-cellulose or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Galvanic action

2.7.1 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion. In order to prevent galvanic corrosion, special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.8 Bimetallic connections

2.8.1 The design is to ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.9 Deck coverings

2.9.1 Where plated decks are sheathed with wood, the sheathing is to be efficiently attached to the deck, caulked and sealed, to the satisfaction of the Surveyor in accordance with the approved drawings.

2.9.2 Deck coverings in the following positions are to be of a type which will not readily ignite where used on decks:

(a) Forming the crown of machinery or cargo spaces within accommodation spaces of cargo craft.

(b) Within accommodation spaces, control stations, stairways and corridors of passenger craft.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength by corrosion.

2.10.2 Where aluminium alloy is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.11 Fracture control

2.11.1 Aluminium alloys in commercial use are in general not subject to unstable crack growth in an elastic stress field because fracture toughness is high. However, for alloys with higher strength and/or temper, special tests may be required to provide information on fracture toughness.

2.11.2 Construction procedures, materials and welding are to be in accordance with the requirements of this Chapter such that stress corrosion cracking is avoided.

2.11.3 High local stresses are to be avoided by the use of suitable design detail, *see also* LR's *Guidance Notes for Structural Details*.

■ *Section 3* Procedures for welded construction

3.1 General

3.1.1 Except as otherwise indicated below, all welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.1.2 The requirements of this Section are applicable to aluminium alloys welded using the metal inert gas (MIG) or tungsten inert gas (TIG) processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are to clearly indicate details of the welded connections of the main structural members, including the type, disposition and size of welds.

3.3 Welding consumables

3.3.1 All welding consumables are to be approved by LR and are to be suitable for the type of joint and grade of material, *see* Ch 11,9 of the Rules for Materials.

3.3.2 The 5083 and 5086 alloys are normally welded using the 5356, 5556 or 5183 consumables and the 6061 and 6082 alloys are normally welded using the 4043 consumables.

3.3.3 Only approved filler wires are to be used. Testing requirements for welding consumables are contained in the Rules for Materials.

3.3.4 Cast aluminium alloys are not in general to be welded directly to wrought high magnesium alloys unless the welding is carried out in accordance with an agreed procedure.

3.3.5 Special care is to be taken in the distribution, storage and handling of all welding consumables. Aluminium filler metals are to be kept in a heated dry storage area with a relatively uniform temperature. Condensation on the metal surface during storage and use is to be avoided. Other welding consumables such as bare wire and welding studs are to be stored under dry conditions to prevent corrosion. Effective facilities for protecting consumables are to be provided close to working areas.

3.4 Defined practices and welding sequence

3.4.1 Details of the welding procedures and the sequence of welding assemblies and joining up of assemblies are to be submitted.

3.4.2 The proposed sequence of welding is to be agreed with the Surveyor prior to construction.

3.4.3 The type and disposition of connections and sequences of welding are to be so planned that any restraint during welding operations is reduced to a minimum.

3.4.4 Special attention is to be given to the examination of plating in way of all lifting eye plate positions to ensure freedom from cracks. This examination is not restricted to the positions where eye plates have been removed but includes the positions where lifting eye plates are permanent fixtures.

3.4.5 Careful consideration is to be given to assembly sequence and overall shrinkage of plate panels, assemblies, etc., resulting from welding processes employed. Welding is to proceed systematically with each welded joint being completed in correct sequence without undue interruption. Where practicable, welding is to commence at the centre of a joint and proceed outwards or at the centre of an assembly and progress outwards towards the perimeter so that each part has freedom to move in one or more directions. Generally, the welding of stiffener members including transverses, frames, girders, etc., to welded plate panels by automatic processes is to be carried out in such a way as to minimise angular distortion of the stiffener.

3.4.6 Butt welds are to be finished full at the ends and cut back before welding the seams. Seams are generally not to be welded within 300 mm of an unwelded butt weld or welded across an unwelded butt joint.

3.4.7 The final boring out of propeller brackets and sterntubes and the fit-up and alignment of rudder bearings and jet units are to be carried out after the major part of the welding of the aft end of the craft is complete. The contacts between rudder stocks and propeller shafts with bearings are to be checked before the final mounting.

3.4.8 Precautions are to be taken to screen and pre-warm the general and local weld areas as necessary. Surfaces are to be dry.

3.5 Structural arrangements and access

3.5.1 Ceilings, cabin sole, side and overhead linings are to be secured in such a manner as to be easily removed for the maintenance and inspection of the structure below.

3.5.2 Structural arrangements are to be such as will allow adequate ventilation and access for preheating, where required, and for the satisfactory completion of all welding operations. Welded joints are to be so arranged as to facilitate the use of downhand welding wherever possible.

3.6 Heat treatment

3.6.1 Pre-heating is to be applied in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.6.2 For aluminium-magnesium alloys, the preheating temperature is to be limited to 60°C to avoid the risk of stress corrosion cracking.

3.6.3 With the 6000 series heat-treatable alloys, it is sometimes beneficial to apply a post-weld heat treatment in the form of artificial ageing. The procedure to be used depends on the alloy and, in order to quantify the benefits, tests are required using representative specimens which accurately simulate the true situation in terms of metal thickness, geometry, filler metal and welding parameters, as well as the post-weld treatment employed.

3.7 Testing

3.7.1 Inspection of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

3.7.2 Checkpoints for volumetric examination are to be selected so that a representative sample of welding is examined.

3.7.3 Typical locations for volumetric examination and number of checkpoints to be taken are shown in Table 2.3.1. A list of the proposed items to be examined is to be submitted for approval.

3.8 Acceptance criteria

3.8.1 All finished welds are to be sound and free from cracks and substantially free from lack of fusion, incomplete penetration, porosity and tungsten inclusions. The surfaces of welds are to be reasonably smooth and substantially free from undercut and overlap. Care is to be taken to ensure that the specified dimensions of welds have been achieved and that both excessive reinforcement and underfill of welds are avoided.

3.8.2 The quality and workmanship of welding of all fittings and attachments to main structure, both permanent and temporary, are to be equivalent to those of the main hull structure.

Table 2.3.1 Non-destructive examinations of welds

Volumetric non-destructive examinations – Recommended extent of testing, *see* 3.7.3		
Item	Location	Checkpoints, *see* Note 1
Intersections of butts and seams of fabrication and section welds	Throughout: hull envelope longitudinal and transverse bulkheads inner bottom and hopper bottom	The summation of checkpoint lengths (*see* Note 2) examined at intersections is to be L, where L is the overall length of the ship in metres
Butt welds in plating	Throughout	1 m in 25 m, *see* Note 3
Seam welds in plating	Throughout	1 m in 100 m
Butts in longitudinals	Hull envelope within 0,4L amidships Hull envelope outside 0,4L amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: connection of stool and bulkhead to lower stool shelf plating vertical corrugations to an inner bottom hopper knuckles sheerstrake to deck stringer hatchways coaming to deck	Throughout	1 m in 20 m

NOTES
1. The length of each checkpoint is to be between 0,3 m and 0,5 m.
2. For checkpoints at intersections the measured dimension of length is to be in the direction of the butt weld.
3. Checkpoints in butt welds and seam welds are in addition to those at intersections.
4. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations.
5. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects, such as lack of fusion or incomplete penetrations, are repeatedly observed.

3.8.3 Visual examination of all welds is to be supplemented by non-destructive testing as considered necessary by the Surveyor.

3.8.4 Fairing, by linear or spot heating, to correct distortions due to welding is, in general, not to be carried out unless procedures have been approved to ensure that the properties of the material are not adversely affected. Visual examination of all heat affected areas and welds in the vicinity is to be carried out to ensure freedom from defects.

■ *Section 4* Joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, aluminium/wood connection, riveting of light structure and chemical bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:
(a) Weld throat thickness or leg lengths.
(b) Grades, tempers, and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be submitted for approval, *see also* 4.20.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc., before the table is welded.

4.4.3 For guidance purposes, a number of typical joint preparations for TIG and MIG welding are shown in Tables 2.4.1 and 2.4.2 respectively.

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_p \times \text{Weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_p, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillets, in mm

t_p = plate thickness, in mm, on which weld fillet size is based, *see* 4.5.4.

Weld factors are contained in Table 2.4.3.

NOTE:

for double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken as 1 (*see* 4.8.1).

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth be greater than or equal to 1,5, *see* Fig. 2.4.1.

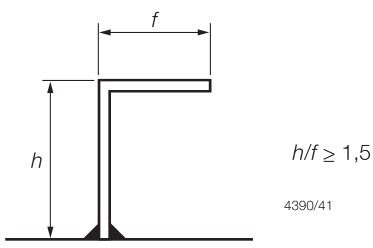


Fig. 2.4.1 Web height/flange breadth ratio

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in 4.5.1 is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet will be specially considered.

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in Table 2.4.4 are to be complied with.

4.7 Single sided welding

4.7.1 Temporary backing bars for single sided welding may be austenitic stainless steel, glass tape, ceramic, or anodised aluminium of the same material as the base metal. Backing bars are not to be made of copper to avoid weld contamination and corrosion problems.

4.7.2 Temporary backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with 4.5.1 taking $\left(\frac{d}{s}\right)$ equal to 1.

4.8.2 Double continuous welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections, including hatch coamings, companionways and other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine seatings.
(d) Bottom framing structure of high speed craft in way of machinery and jet room spaces as appropriate.
(e) The side and bottom shell structure in the impact area of high speed motor craft.
(f) The underside of the cross-deck structure in the impact area of high speed multi-hull craft.
(g) Structure in way of ride control systems, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.
(h) The shell structure in the vicinity of the propeller blades.
(j) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(k) Primary and secondary members to plating in way of end connections, and end brackets to plating in the case of lap connections.
(l) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.

Table 2.4.1 Typical joint preparations for TIG welding of aluminium alloys

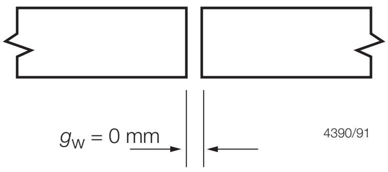
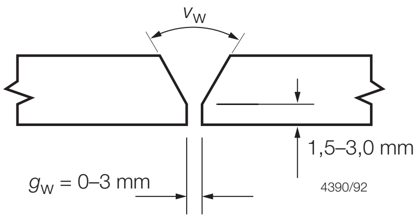
Thickness (mm)	Joint design	Welding position/comments
2,5 – 3,0		Flat Horizontal Vertical Overhead
3,0 – 10,0		Flat and Vertical V = 60° Horizontal and Overhead V = 90° – 110°
Symbols and definitions		
g_W = weld gap, in mm V_W = weld preparation angle, in degrees		

Table 2.4.2 Typical joint preparations for semi-automatic MIG welding

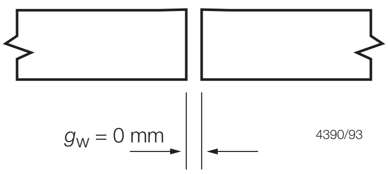
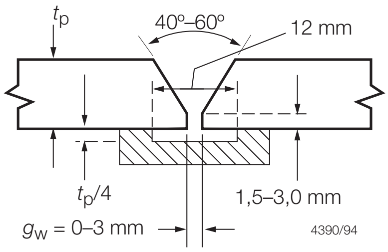
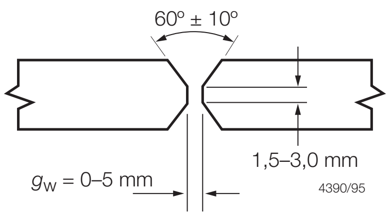
Thickness (mm)	Joint design	Welding position/comments
5,0 – 6,5		Flat
7,0 – 15,0		Flat Horizontal Vertical Overhead One sided welding with temporary backing
12,0 – 25,0		All positions
Symbols and definitions		
t_p = plate thickness, in mm g_W = weld gap, in mm		

Table 2.4.3 **Weld factors** (*see continuation*)

Item	Weld Factor	Remarks
(1) General application:		except as required below
(a) Watertight plate boundaries	0,34	
(b) Non-tight plate boundaries	0,13	
(c) Longitudinals, frames, beams, and other secondary members to shell, deck, or bulkhead plating	0,10 0,13 0,21	 in tanks in way of end connections
(d) Panel stiffeners	0,10	
(e) Overlap welds generally	0,27	
(f) Longitudinals of the flat-bar type to plating		*see* 4.8.2
(2) Bottom construction:		
(a) Non-tight centre girder: • to keel • to inner bottom	 0,27 0,21	 no scallops
(b) Non-tight boundaries of: • floors, girders and • brackets	 0,21 0,27	 in way of 0,2 x span at ends in way of brackets at lower end of main frame
(c) Inner bottom longitudinals, or face flat to floors reverse frames	0,13	
(d) Connection of floors to inner bottom where bulkhead supported on tank top. The supporting floors are to be continuously welded to the inner bottom	0,44	Weld size based on floor thickness Weld material compatible with floor material
(3) Hull framing:		
(a) Webs of web frames and stringers: • to shell • to face plate	 0,16 0,13	
(4) Decks and supporting structure:		
(a) Weather deck plating to shell Other decks to shell and bulkheads (except where forming tank boundaries)	0,44 0,21	 generally continuous
(b) Webs of cantilevers to deck and to shell in way of root bracket	0,44	
(c) Webs of cantilevers to face plate	0,21	
(d) Girder webs to deck clear of end brackets	0,10	
(e) Girder webs to deck in way of end brackets	0,21	
(f) Web of girder to face plate	0,10	
(g) Pillars: • fabricated • end connections • end connections (tubular)	 0,10 0,34 full penetration	
(h) Girder web connections and brackets in way of pillar heads and heels	0,21	continuous

Table 2.4.3 **Weld factors** (*see continuation*)

Item	Weld Factor	Remarks
(5) Bulkheads and tank construction:		
(a) Plane and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead plating Weld material to be compatible with bulkhead plating material
(b) Secondary members where acting as pillars	0,13	
(c) Non-watertight pillar bulkhead boundaries	0,13	
(d) Perforated flats and wash bulkhead boundaries	0,10	
(e) Deep tank horizontal boundaries at vertical corrugations	full penetration	
(6) Structure in machinery space:		
(a) Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
(b) Floors to centre girder in way of engine thrust bearers	0,27	
(c) Floors and girders to shell and inner bottom	0,21	
(d) Main engine foundation girders: • to top plate • to hull structure	deep penetration to depend on design	edge to be prepared with maximum root $0{,}33t_p$ deep penetration, generally
(e) Floors to main engine foundation girders	0,27	
(f) Brackets, etc., to main engine foundation girders	0,21	
(g) Transverse and longitudinal framing to shell	0,13	
(7) Superstructures and deckhouses:		
(a) Connection of external bulkheads to deck	0,34 0,21	1st and 2nd tier erections elsewhere
(b) Internal bulkheads	0,13	
(8) Steering control systems:		
(a) Rudder: • Fabricated mainpiece and • mainpiece to side plates and webs	0,44	
(b) Slot welds inside plates	0,44	
(c) Remaining construction	0,21	
(d) Fixed and steering nozzles: • Main structure • Elsewhere	0,44 0,21	
(e) Fabricated housing and structure of thruster units, stabilisers, etc.: • Main structure • Elsewhere	0,44 0,21	

Table 2.4.3 Weld factors (*conclusion*)

Item	Weld Factor	Remarks
(9) Miscellaneous fittings and equipment:		
(a) Rings for manhole type covers, to deck or bulkhead	0,34	
(b) Frames of shell and weathertight bulkhead doors	0,34	
(c) Stiffening of doors	0,21	
(d) Ventilator, air pipes, etc., coamings to deck	0,34 0,21	Load Line Positions 1 and 2 elsewhere
(e) Ventilator, etc., fittings	0,21	
(f) Scuppers and discharges, to deck	0,44	
(g) Masts, crane pedestals, etc., to deck	0,44	full penetration welding may be required
(h) Deck machinery seats to deck	0,21	generally
(j) Mooring equipment seats	0,21	generally, but increased or full penetration may be required
(k) Bulwark stays to deck	0,21	
(l) Bulwark attachment to deck	0,34	
(m) Guard rails, stanchions, etc., to deck	0,34	
(n) Bilge keel ground bars to shell	0,34	continuous fillet weld, minimum throat thickness 4 mm
(o) Bilge keels to ground bars	0,21	light continuous or staggered intermittent fillet weld, minimum throat thickness 3 mm
(p) Fabricated anchors		full penetration

Table 2.4.4 Throat thickness limits

Item	Throat thickness mm	
	Minimum	Maximum
(1) Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2) Intermittent welding	$0{,}27t_p$	$0{,}44t_p$ or 4,5
(3) Overriding minimum:		
(a) Continuous welds	2,5	
(b) Intermittent welds:		
(i) Plate thickness $t_p \leq 7{,}5$ mm Hand or automatic welding	3,0	
Automatic deep penetration welding	3,0	
(ii) Plate thickness $t_p \geq 7{,}5$ mm Hand or automatic welding	3,25	
Automatic deep penetration welding	3,0	

NOTES
1. In all cases the limiting maximum value is to be taken as the greatest of the applicable values above.
2. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.

4.9 Intermittent welding (staggered)

4.9.1 Staggered intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.10 Intermittent welding (chain)

4.10.1 Chain intermittent welding may be used, outside of the impact area in the bottom shell or crossdeck structure of high speed craft.

4.11 Connections of primary structure

4.11.1 Depending on the structural design of the joint and design loads on the primary member, full penetration welding of flanges and web plates may be required to attain full section properties in the end connections of primary members. *See also* Pt 6, Ch 3,1.22. Otherwise weld factors for the connections of primary structure are given in Table 2.4.3.

4.11.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0{,}85 \text{ x stiffener spacing}}{\text{length of web plating between notches}}$$

4.11.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.12 Primary and secondary member end connection welds

4.12.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.12.2 The welding of secondary member end connections is to be not less than as required by Table 2.4.5. Where two requirements are given the greater is to be complied with.

4.12.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.12.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the cross-sectional area of the member.

4.13 Weld connection of strength deck plating to sheerstrake

4.13.1 The weld connection of strength deck plating to sheerstrake is to be by double continuous fillet welding with a weld factor of 0,44. The welding procedure, including joint preparation, is to be specified and the procedure qualified and approved for individual Builders.

4.14 Air and drain holes

4.14.1 Air and drain holes are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges, *see also* LR's *Guidance Notes for Structural Details*.

4.15 Notches and scallops

4.15.1 Notches and scallops are to be kept clear of the toes of brackets, etc. Openings are to be well rounded with smooth edges. Details of scallops are shown in Fig. 13.2.1 in Chapter 13 of the Rules for Materials.

4.15.2 Scallops are to be of such a size, and in such a position that a satisfactory weld can be made around the ends of openings.

Table 2.4.5 Secondary member end connection welds

Connection	Weld area, A_w, in cm^2	Weld factor
(1) Stiffener welded direct to plating	$0{,}25A_s$ or 6,5 cm^2 whichever is the greater	0,34
(2) Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:		
(a) in dry space	$1{,}2\sqrt{Z}$	0,27
(b) in tank	$1{,}4\sqrt{Z}$	0,34
(c) main frame to tank side bracket in $0{,}15L_R$ forward	as (a) or (b)	0,34
(3) Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4) Stiffener to plating for 0,1 x span at ends, or in way of the end bracket if that be greater	—	0,34
Symbols		
A_s = cross section area of the stiffener, in cm^2 A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm Z = the section modulus, in cm^3, of the stiffener on which the scantlings of the end bracket are based.		
NOTE For maximum and minimum weld fillet sizes, *see* Table 2.4.4.		

4.16 Watertight collars

4.16.1 Watertight collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries, *see also* LR's *Guidance Notes for Structural Details*.

4.17 Lug connections

4.17.1 The area of the weld connecting secondary stiffeners to primary structure in the bottoms of the hulls and cross-deck structure in areas subjected to impact pressures is to be not less than the shear area from the Rules. This area is to be obtained by fitting two lugs or by other equivalent arrangements. Some typical lug connections are shown in Fig. 2.4.2 and Fig. 3.1.7 in Chapter 3.

4.17.2 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of fenders, etc.).

4.17.3 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

4.18 Insert plates

4.18.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

4.18.2 The corners of insert plates are to be suitably radiused.

4.19 Doubler plates

4.19.1 Doubler plates are to be avoided in areas where corrosion may be a problem and access for inspection and maintenance is limited.

4.19.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

4.20 Joint preparation

4.20.1 Typical butt joints are shown in Tables 2.4.1 and 2.4.2, *see also* LR's *Guidance Notes for Structural Details*.

4.21 Construction tolerances

4.21.1 The minimum requirements for construction tolerances are to be in accordance with Pt 3, Ch 1,8.

4.22 Riveting of light structure

4.22.1 Where it is proposed to adopt riveted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate riveting schedule is to be submitted.

4.22.2 Samples may be required of typical riveted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

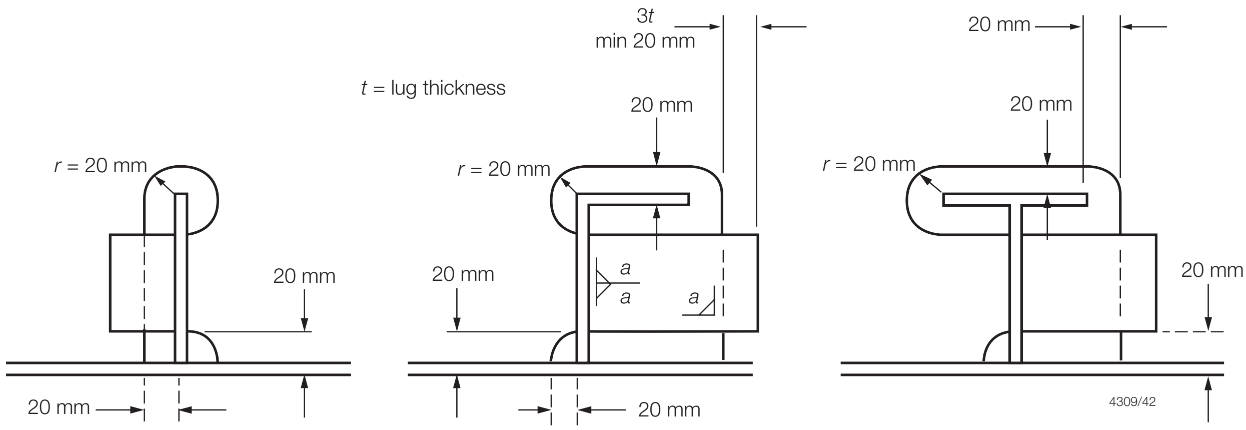


Fig. 2.4.2 Typical lug connections

4.22.3 Where riveting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

4.22.4 Where two dissimilar metals are to be joined by riveting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements should be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

4.22.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

4.22.6 Aluminium alloy rivets in accordance with Ch 8,2 of the Rules for Materials are to be used where practicable. However, in the case of composite structures, including steel and GRP, consideration will be given to the use of steel rivets. In such cases, the mating surfaces are to be coated with a sealing paint.

4.22.7 Sealing paints or compounds are not to be used with hot driven rivets.

4.23 Chemical bonding of structure

4.23.1 Where chemical bonding of aluminium alloy of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance.

4.23.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

4.23.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

4.23.4 Bonded joints are suitable for carrying shear loads, but are not in general to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

4.23.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be to be developed. Entrained air pockets are to be avoided.

4.23.6 The use of adhesives for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

4.24 Triaxial stress considerations

4.24.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design. Detailed joint design is of particular importance in aluminium structures more so than many other materials. Some recommendations in this respect are contained in LR's *Guidance Notes for Structural Details*.

4.25 Butt straps

4.25.1 In general, the scantling derivation of welded structures are to be determined using the mechanical properties of the aluminium alloy in the welded condition in accordance with 2.4. However, where stiffeners are butt welded, special consideration will be given to the use of suitable butt straps on the flanges which sufficiently reinforce the area of the weld to allow the scantlings to be determined using the unwelded mechanical properties. The butt weld is to be completed and generally made flush with the flange of the stiffening member before the butt strap is fitted and the

butt strap weld is to be continuous. Where this jointing method is proposed, the scantlings, arrangements and locations of all joints and butt straps are to be submitted. Additionally, LR may require mechanical tests to be carried out to demonstrate the effectiveness of such arrangements.

4.26 Extruded 'planking'

4.26.1 Joints between adjacent extruded aluminium alloy planking, and the attachment of the planking to the supporting structure is in general to be by means of continuous welding.

4.26.2 The planking is generally not to be included in the determination of the section properties for both section modulus and inertia. However, special consideration will be given to the inclusion of such materials on the basis of the efficiency of the connection to the supporting structure.

4.27 Aluminium/steel transition joints

4.27.1 Provision is made in this Section for explosion bonded composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also* Ch 8,4 of the Rules for Materials.

4.27.2 Transition joints are to be manufactured by an approved producer in accordance with an approved specification which is to include the maximum temperature allowable at the interface during welding.

4.27.3 The aluminium material is to comply with the requirements of Section 2 and the steel is to be of an appropriate grade complying with the requirements of Ch 3,2 of the Rules for Materials.

4.27.4 Alternative materials which comply with International, National or proprietary specifications may be accepted provided that they give equivalence to the requirements of 4.31.3 or are approved for a specific application.

4.27.5 Intermediate layers between the aluminium and steel may be used, in which case the material of any such layer is to be specified by the manufacturer and is to be recorded in the approval certificate. Any such intermediate layer is then to be used in all production transition joints.

4.27.6 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

4.28 Aluminium/wood connection

4.28.1 To minimise corrosion of aluminium when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the aluminium in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

4.28.2 Timbers such as western red cedar, oak and chestnut are not, unless well seasoned, to be directly in contact with aluminium.

4.28.3 Timber preservatives of the following types should be avoided: copper napthanate, copper-chrome-arsenate, borax-boric acid.

Section

■ *Section 1*
General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of aluminium construction as defined in Pt 1, Ch 2,2.

1.2 General

1.2.1 The formulae contained within this Chapter are to be used in conjunction with the design loadings from Part 5 to determine the Rule scantling requirements.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
l = stiffener overall length, in metres
l_e = effective span length, in metres, as defined in 1.19
p = design pressure, in kN/m^2, as given in Part 5
s = stiffener spacing, in mm
t_p = plating thickness, in mm
A_w = shear area of stiffener web, in cm^2
B = moulded breadth of craft, in metres, as defined in Pt 3, Ch 1,6
E = modulus of elasticity, in N/mm^2
I = moment of inertia, in cm^4
L_R = Rule length of craft, in metres, as defined in Pt 3, Ch 1,6
Z = section modulus of the stiffening member, in cm^3
β = panel aspect ratio correction factor as defined in 1.15
γ = convex curvature correction factor as defined in 1.14
σ_a = guaranteed minimum 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2, *see also* Ch 2,2.4.2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.6 Rounding policy for Rule plating thickness

1.6.1 Where plating thicknesses as determined by the Rules require to be rounded then this is to be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.7 Dimensional tolerance

1.7.1 Dimensional tolerances for materials are to be in accordance with Chapter 8 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), or an acceptable National or International Standard.

1.7.2 The under thickness tolerance acceptable for classification is to be considered as the lower limit of a range of thickness tolerance which could be found in the normal production of a conventional rolling mill manufacturing material, on average, to the nominal thickness.

1.7.3 The Owners and Builders may agree in individual cases whether they wish to specify a more stringent under thickness tolerance than that given in 1.7.2.

1.7.4 The minus tolerance on sections (except for wide flats) is to be in accordance with a National or International Standard.

1.7.5 The thickness of plates and strip is to be measured at random locations whose distance from an edge is to be at least 25 mm. Local surface depressions resulting from imperfections and ground areas resulting from the elimination of defects may be disregarded provided that they are in accordance with the requirements of a National or International Standard.

1.7.6 The responsibility for maintaining the required tolerances and making the necessary measurements rests with the manufacturer/Builder. Occasional checking by the Surveyor does not absolve the manufacturer/Builder from the responsibility.

1.8 Material properties

1.8.1 The basic grade of aluminium alloy is taken as marine grade 5083-0 with the following mechanical properties:

	N/mm^2
0,2 per cent proof stress (minimum)	125
Tensile strength	260
Modulus of elasticity	69×10^3

1.8.2 Where other alloy grades with differing mechanical properties are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, section modulus, inertia and cross-sectional area by use of the following correction factors:

(a) Plating thickness factor = $\sqrt{k_a}$

(b) Section modulus and cross section area factor = k_a where k_a is as defined in 1.5.1.

1.9 High strength sheet and plate

1.9.1 Particular attention is to be given to the welding procedures for the welding of high strength sheet and plate. The 0,2 per cent yield strength values in the welded condition will, in general, be significantly less than in the unwelded condition. These reduced values are to be used in the determination of the Rule scantlings.

1.10 High strength extrusions

1.10.1 The requirements of 1.9 are to be complied with. However, special consideration will be given to the use of un-welded strength properties for use in the determination of the Rule scantlings provided that suitable compensation is provided in way of welding on the face of the stiffener. This compensation can be provided by butt-straps or other acceptable arrangements, *see also* Ch 2,4.28.

1.10.2 The application of high strength extrusions is in general limited to superstructures, deckhouses, decks and bulkheads. Special consideration will be given to their use in other areas.

1.10.3 Butt welds and seams are to be carefully positioned clear of areas of high stress and where practicable are to be orientated parallel to the direction of the main stresses.

1.11 Effective width of attached plating

1.11.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

1.11.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm and a breadth b_e, in mm, b_e is as defined in 1.11.3 and 1.11.4.

1.11.3 The effective width of attached plating to secondary members b_e is to be taken as $2t_p \sqrt{E/\sigma_a}$ but not greater than s. σ_a is not to be taken as greater than 169 N/mm^2 for aluminium alloy. E, s and σ_a are as defined in 1.5.1.

1.11.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.) b_e is to be taken as bf, where b and f are as defined in Pt 3, Ch 2,3.2.1.

1.11.5 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when calculating the actual section modulus and inertia of the primary stiffening members, i.e. the full section modulus and inertia are to be provided by the primary stiffening member only, *see also* Ch 2,4.27.

1.12 Other materials

1.12.1 Special consideration will be given to the use of materials other than aluminium alloy. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal.

1.13 Fibre reinforced plastic (FRP)

1.13.1 The use of FRP in construction is to be in accordance with Part 8.

1.14 Convex curvature correction

1.14.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor
= $1 - h/s$, and is not to be taken as less than 0,7
h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports

See Fig. 3.1.1.

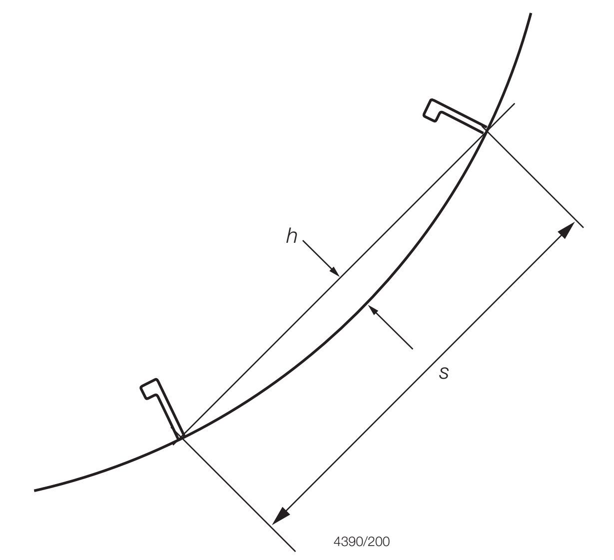


Fig. 3.1.1 Convex curvature

1.15 Aspect ratio correction

1.15.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor
= $A_R (1 - 0{,}25 A_R)$ for $A_R \leq 2$
= 1 for $A_R > 2$

where
A_R = panel aspect ratio
= panel length/panel breadth.

1.16 Plating general

1.16.1 The requirements for the thickness of plating, t_p, is, in general, to be in accordance with the following:

$$t_p = 22{,}4 s \gamma \beta \sqrt{\frac{p}{f_\sigma \sigma_a}} \times 10^{-3} \text{ mm}$$

where
f_σ = limiting bending stress coefficient for the plating element under consideration is given in Table 7.3.1 in Chapter 7.
s, γ, β, p, σ_a are as defined in 1.5.1.

1.17 Stiffening general

1.17.1 The requirements for section modulus, inertia and web area of stiffening members are in general to be in accordance with the following:

(a) Section modulus:

$$Z = \Phi_Z \frac{p\, s\, l_e^2}{f_\sigma \sigma_a} \text{ cm}^3$$

where
Φ_Z = section modulus coefficient dependent on the loading model assumption taken from Table 3.1.1
f_σ = limiting bending stress coefficient for stiffening member given in Table 7.3.1 in Chapter 7.
p, s, l_e and σ_a are as defined in 1.5.

(b) Inertia:

$$I = \Phi_I f_\delta \frac{p\, s\, l_e^3}{E} \times 100 \text{ cm}^4$$

where
Φ_I = inertia coefficient dependent on the loading model assumption taken from Table 3.1.1
f_δ = limiting deflection coefficient for stiffener member given in Table 7.2.1 in Chapter 7.
p, s, l_e and E are as defined in 1.5.1.

(c) Web area:

$$A_w = \Phi_A \frac{p\, s\, l_e}{100 f_\tau \tau_a} \text{ cm}^2$$

where
Φ_A = web area coefficient dependent on the loading model assumption taken from Table 3.1.1
f_τ = limiting shear stress coefficient for stiffener member given in Table 7.3.1 in Chapter 7
p, s, l_e and τ_a are as defined in 1.5.1.

1.18 Geometric properties and proportions of stiffener sections

1.18.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with Table 3.1.2.

Table 3.1.1 Section modulus, inertia and web area coefficients

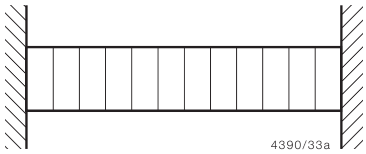
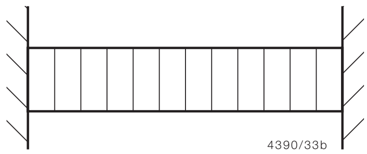
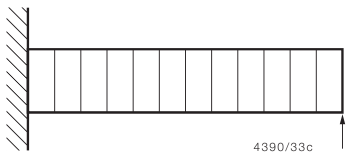
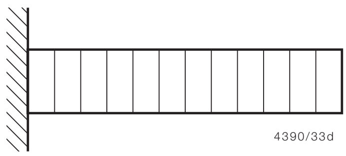
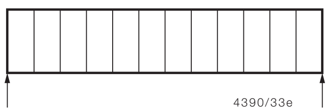
Load model	Position			Position	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
	1	2	3					
(a)				1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)				1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)				1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)				1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)				1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

Table 3.1.2 Stiffener proportions

Type of stiffener	Requirement
(1) Flat bar	Minimum web thickness: $t_w = d_w/15 \geq 3$ mm
(2) Rolled or built sections	(a) Minimum web thickness: $t_w = d_w/50 \geq 3$ mm (b) Maximum unsupported face plate (or flange) width: $b_f = 16\ t_f$
Symbols	
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm	

1.19 Determination of span point

1.19.1 The effective length of span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members: The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see* Fig. 3.1.2. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members: The span point is to be taken at a point distant, b_e from the end of the member, where

$$b_e = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_e, b_b, d_w and d_B are as shown in Fig. 3.1.2.

1.19.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

1.19.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

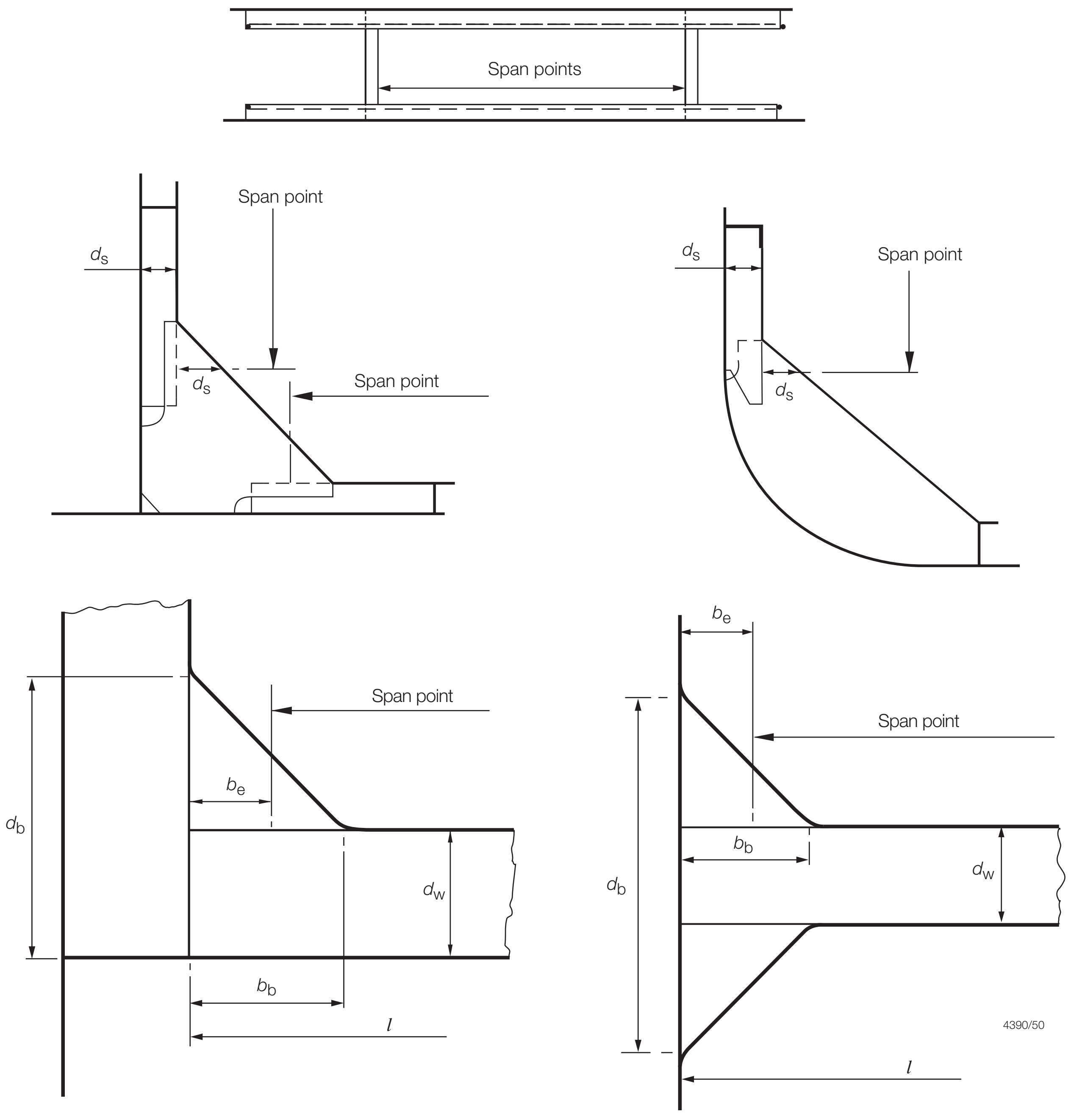


Fig. 3.1.2 Span points

1.19.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span may be measured as in Fig. 3.1.2.

1.19.5 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

1.20 Secondary member end connections

1.20.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also* Ch 2,4.15 and Table 2.4.5 in Chapter 2.

1.20.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.20.3 The scantlings of secondary member end connections are to be in accordance with 1.21.

1.21 Scantlings of end brackets

1.21.1 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the end brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.21.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0{,}5L_R$ – modulus of the frame.
(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

1.21.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of 1.18 are to be satisfied.

1.21.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.3.

1.21.5 The lengths, a and b of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $a + b \geq 2{,}0 l_b$
(b) $a \geq 0{,}8 l_b$
(c) $b \geq 0{,}8 l_b$

where a and b are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket.

$$l_b = 90\left(2\sqrt{\frac{Z}{14 + \sqrt{Z}}} - 1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3

In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

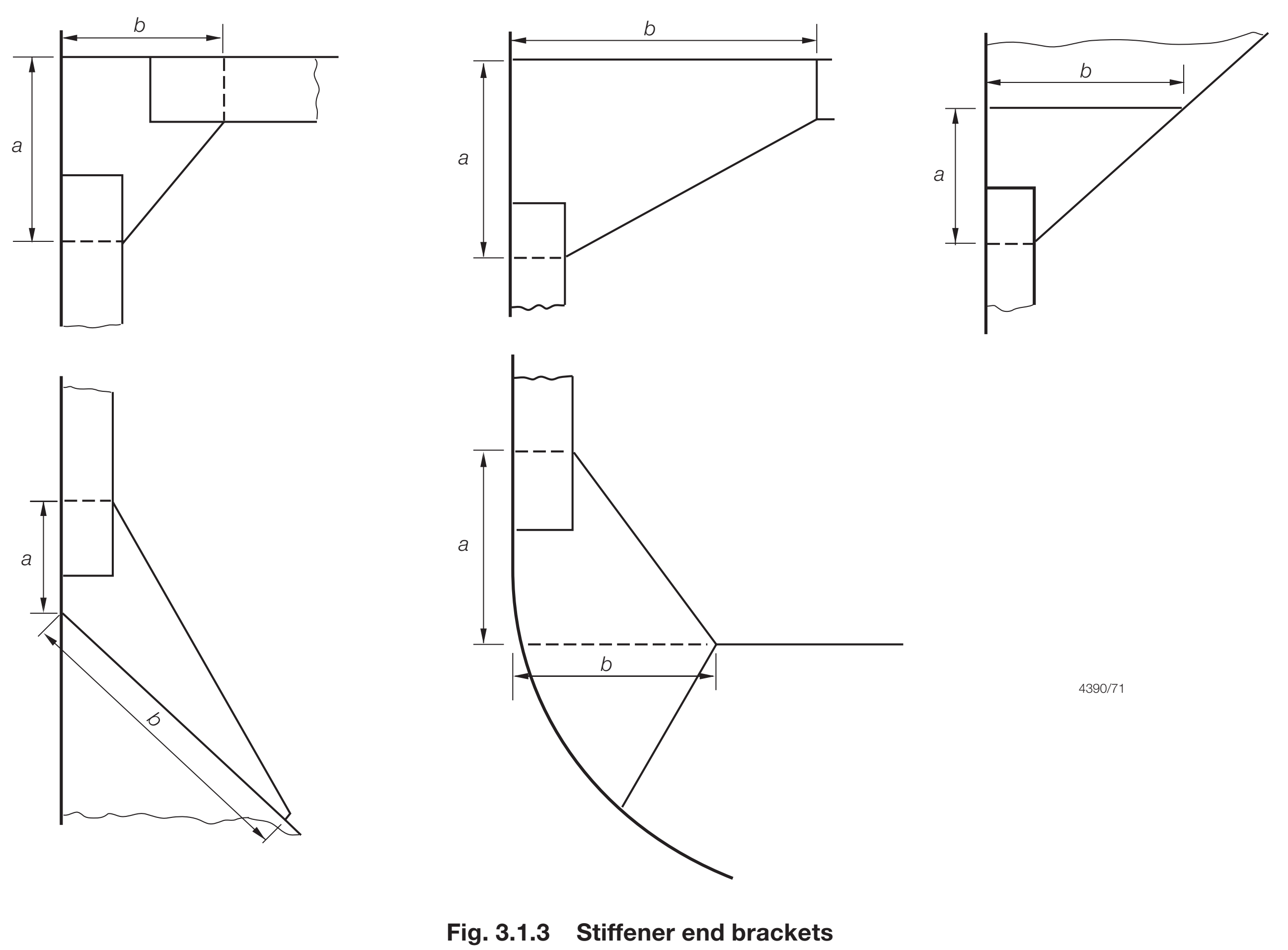


Fig. 3.1.3 Stiffener end brackets

1.21.6 The free edge of the bracket is to be stiffened where any of the following apply:
(a) The section modulus, Z, exceeds 500 cm^3.
(b) The length of free edge exceeds 40 times the bracket thickness.
(c) The bracket is fitted at the lower end of main transverse side framing.

1.21.7 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_f = 30\left(1 + \frac{Z}{1000}\right) \text{ mm}$$

but not less than 40 mm.

1.21.8 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:
(a) $0{,}017 k_a b_f T_B$ cm^2 for offset edge stiffening.
(b) $0{,}014 k_a b_f T_B$ cm^2 for symmetrically placed stiffening.
b_f = breadth of face flat, in mm
T_B = the thickness of the bracket, in mm
k_a is as defined in 1.5.1.

1.21.9 Where the stiffening member is lapped onto the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$, or the depth of stiffener, whichever is the greater.

1.21.10 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

1.21.11 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

1.21.12 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.22 Primary member end connections

1.22.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all craft types are generally to comply with the requirements of 1.21, taking Z as the section modulus of the primary member.

1.22.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.22.3 The members are to have adequate lateral stability and web stiffening and the structure is to be arranged to minimise hard spots and other sources of stress concentration. Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel.

1.22.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.22.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

1.22.6 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening may be required.

1.22.7 The thickness of the bracket is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

1.22.8 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.22.9 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.22.10 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.23 Tank boundary penetrations

1.23.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

1.24 Web stability

1.24.1 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

1.24.2 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars. *See also* LR's *Guidance Notes for Structural Details*.

1.25 Openings in the web

1.25.1 Where openings are cut in the web, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.25.2 Openings are to have smooth edges and well rounded corners.

1.26 Continuity and alignment

1.26.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.26.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.26.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.26.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate is to be fitted, *see* Fig. 3.1.4.

1.26.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.26.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off, *see also* LR's *Guidance Notes for Structural Details*.

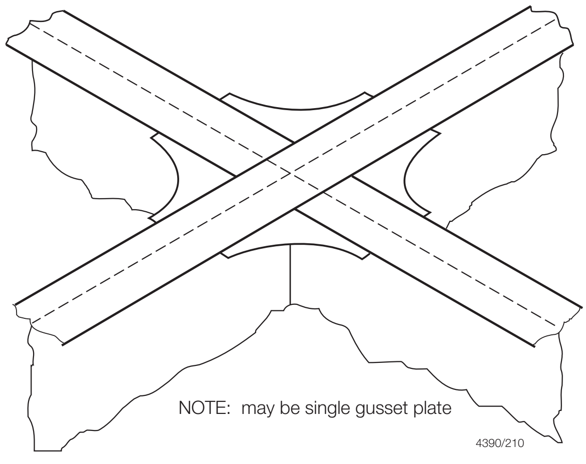


Fig. 3.1.4 Primary member intersection

1.26.7 Particular attention is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiused part of the bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see* Fig. 3.1.5.

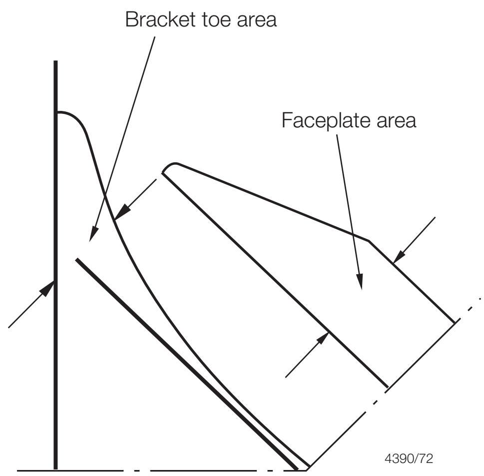


Fig. 3.1.5 Bracket toe construction

1.27 Arrangement with offset stiffener

1.27.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them, *see* Fig. 3.1.6, the collar arrangement for the secondary members are to satisfy the requirements of 1.28. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

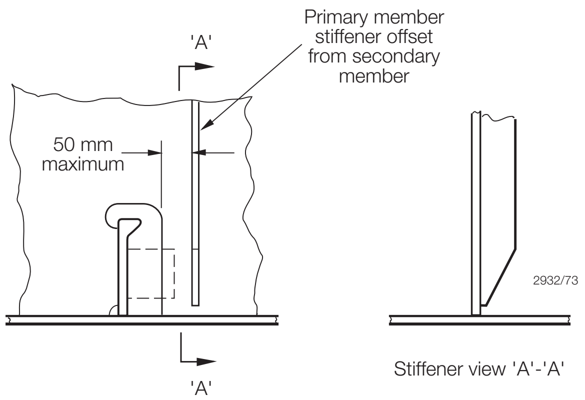


Fig. 3.1.6 Arrangement with offset stiffener

1.27.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.28 Arrangements at intersection of continuous secondary and primary members

1.28.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress.

1.28.2 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 25 mm, whichever is the greater. It is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.1.7, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration, *see also* LR's *Guidance Notes for Structural Details*.

1.28.3 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.28.4 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

1.28.5 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

1.28.6 Where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped.

1.28.7 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing structure on the opposite side of the transverse web or bulkhead.

1.28.8 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of the area of the primary web stiffener in way of the connection.

1.28.9 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

1.29 Openings

1.29.1 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the panel buckling characteristics have been calculated and found satisfactory.

1.29.2 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

1.29.3 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted. Widely spaced air or drain holes may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentration and are, in general, cut clear of the weld connection.

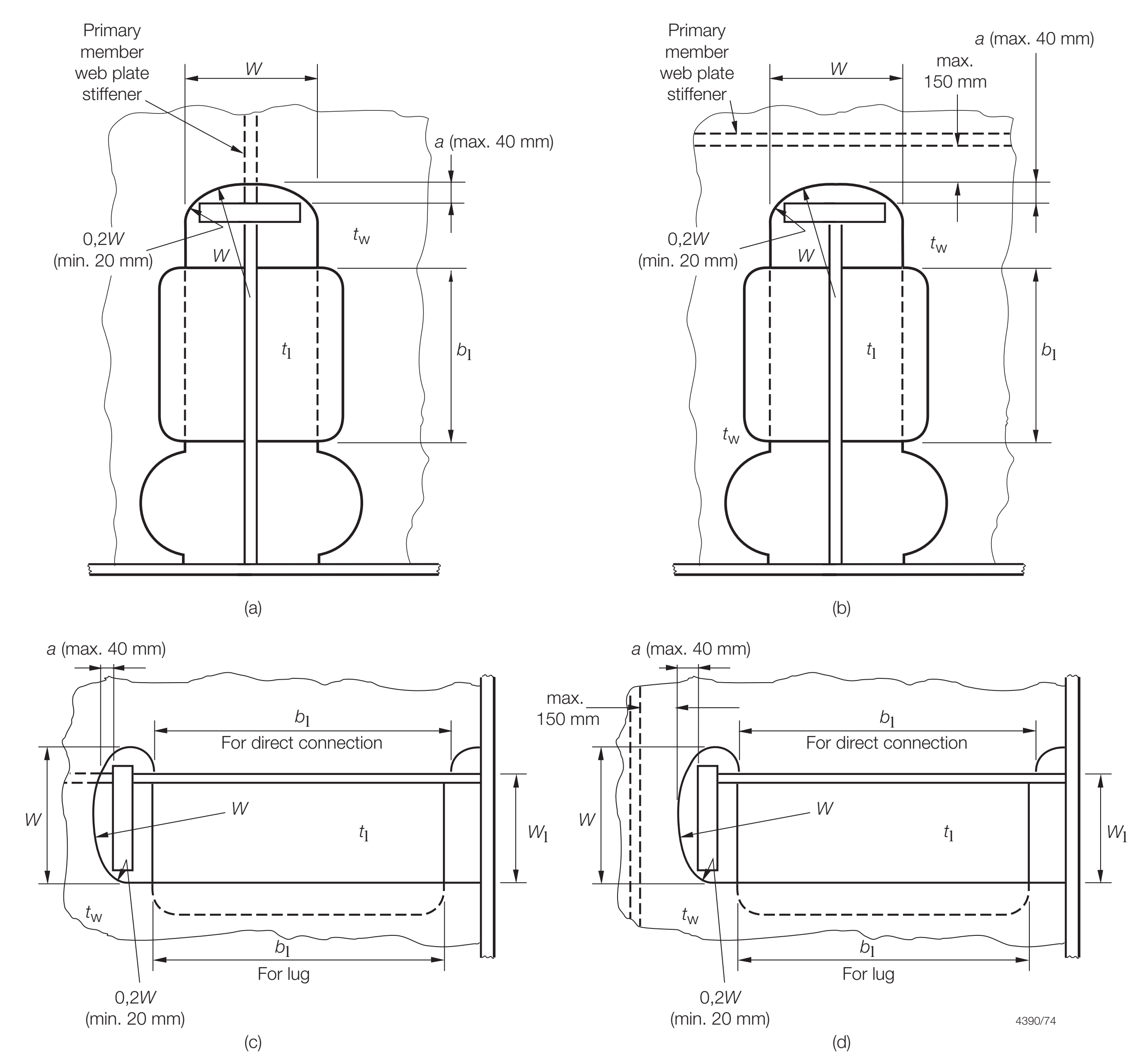


Fig. 3.1.7 Cut-outs and connections

1.30 Fittings and attachments, general

1.30.1 The quality of welding and general workmanship of fittings and attachments as given in 1.31 and 1.32 are to be in accordance with Ch 2,3.8.

1.31 Bilge keels and ground bars

1.31.1 It is recommended that bilge keels are not to be fitted in the forward $0{,}3L_R$ region on ships intended to navigate in ice conditions.

1.31.2 Bilge keels are to be attached to a continuous ground bar as shown in Fig. 3.1.8. Butt welds in shell plating, ground bar and bilge keels are to be staggered.

1.31.3 The thickness of the ground bar is to be not less than the thickness of the bottom shell or 8 mm, whichever is the greater, but need not be taken as greater than 15 mm.

1.31.4 The material class, grade and quality of the ground bar are to be similar to those of the adjacent shell plating.

1.31.5 The ground bar is to be connected to the shell with a continuous fillet weld and the bilge keel to the ground bar with a light continuous fillet weld.

1.31.6 Direct connection between ground bar butt welds and shell plating, and between bilge keel butt welds and ground bar is to be avoided.

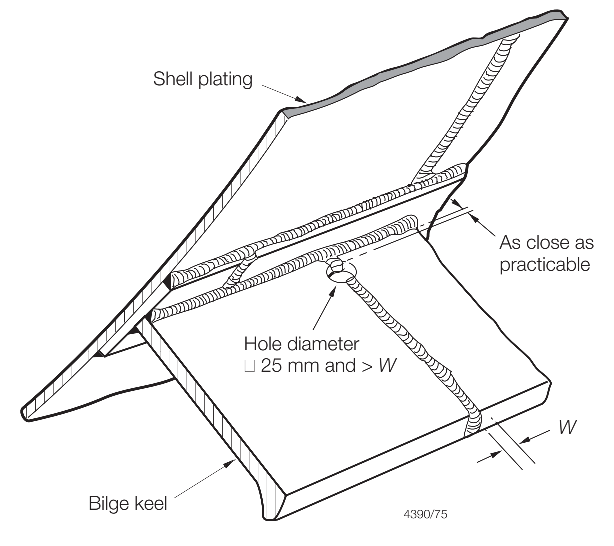


Fig. 3.1.8 Bilge keel construction

1.31.7 The end details of bilge keels and intermittent bilge keels, where adopted, are to be as shown in Fig. 3.1.9.

1.31.8 The ground bar and bilge keel ends are to be tapered or rounded. Where the ends are tapered, the tapers are to be gradual with ratios of at least 3:1, *see* Figs. 3.1.9(a) and (b). Where the ends are rounded, details are to be as shown in Fig. 3.1.9(c). Cut-outs on the bilge keel web within zone 'A' (*see* Fig. 3.1.9(b)) are not permitted.

1.31.9 The end of the bilge keel web is to be between 50 mm and 100 mm from the end of the ground bar, *see* Fig. 3.1.9(a).

1.31.10 An internal transverse support is to be positioned as close as possible to halfway between the end of the bilge keel web and the end of the ground bar, *see* Fig. 3.1.9(b).

1.31.11 Where an internal longitudinal stiffener is fitted in line with the bilge keel web, the longitudinal stiffener is to extend to at least the nearest transverse member outside zone 'A', *see* Fig. 3.1.9(b). In this case, the requirement of 1.31.10 does not apply.

1.31.12 For craft over 65 m in length, L_R, holes are to be drilled in the bilge keel butt welds. The size and position of these holes are to be as illustrated in Fig. 3.1.8. Where the butt weld has been subject to non-destructive examination the stop hole may be omitted.

1.31.13 Bilge keels of a different design from that shown in Fig. 3.1.8 and Fig. 3.1.9 will be specially considered.

1.31.14 Within zone 'B' (*see* Fig. 3.1.9(a)), welds at the ends of the ground bar and the bilge plating, and at the ends of the bilge keel web and ground bar, are to have weld factors of 0,44 and 0,34 respectively. These welds are to be ground and to blend smoothly with the base materials.

1.31.15 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

1.32 Other fittings and attachments

1.32.1 Gutterway bars at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised.

1.32.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centre-line of the face plate in line with the web.

1.32.3 Where necessary in the construction of the craft, lifting lugs may be welded to the hull plating but they are not to be slotted through. Where they are subsequently removed, this is to be carried out by mechanical cutting close to the plate surface, and the remaining material and welding ground off. After removal the area is to be carefully examined to ensure freedom from cracks or other defects in the plate surface.

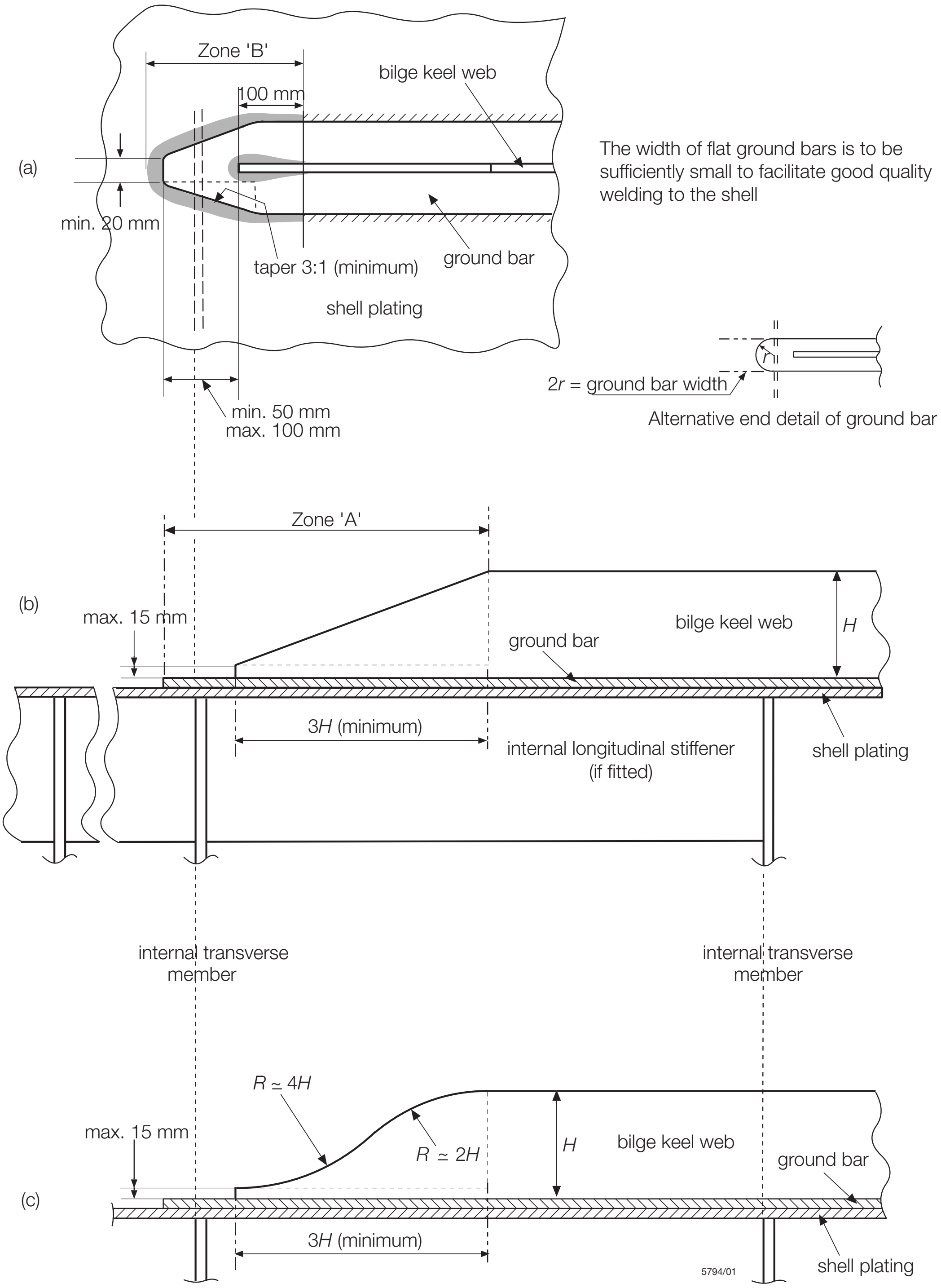


Fig. 3.1.9 Bilge keel end design

Section 2 Minimum thickness requirements

2.1 General

2.1.1 The thickness of plating and stiffeners determined from the Rule scantling requirements is in no case to be less than that given in Table 3.2.1 for the craft type.

2.1.2 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Chapter 6.

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in Table 3.2.1 are based on the assumption that there is negligible loss in strength by corrosion. Where this is not the case the minimum thickness will be specially considered.

Table 3.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Mono-hull	Hydrofoil	Rigid inflatable boat (RIB)
Shell envelope Bottom shell plating	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}0) \geq 4{,}0\ \omega$
Side shell plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Single bottom structure Centre girder web	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
Floor webs	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Side girder webs	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Double bottom structure Centre girder			
(1) Within $0{,}4L_R$ amidships	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(1{,}1\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
(2) Outside $0{,}4L_R$ amidships	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}95\sqrt{L_R} + 1{,}4) \geq 5{,}0\ \omega$
Floors and side girders	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}8\sqrt{L_R} + 1{,}1) \geq 4{,}0\ \omega$
Inner bottom plating	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}7\sqrt{L_R} + 1{,}3) \geq 3{,}5\ \omega$
Bulkheads Watertight bulkhead plating	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}43\sqrt{L_R} + 1{,}2) \geq 3{,}0\ \omega$
Deep tank bulkhead plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}5\sqrt{L_R} + 1{,}4) \geq 3{,}5\ \omega$
Lower deck/Inside deckhouse	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}3\sqrt{L_R} + 1{,}3) \geq 3{,}0\ \omega$
Superstructures and deckhouses Superstructure side plating	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}4\sqrt{L_R} + 1{,}1) \geq 3{,}0\ \omega$
Deckhouse front 1st tier	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}62\sqrt{L_R} + 1{,}8) \geq 3{,}5\ \omega$
Deckhouse front upper tiers	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}55\sqrt{L_R} + 1{,}5) \geq 3{,}0\ \omega$
Deckhouse aft	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$	$\omega\ \sqrt{k_m}\,(0{,}25\sqrt{L_R} + 0{,}7) \geq 2{,}5\ \omega$
Pillars Wall thickness of tubular pillars	$\omega\ \sqrt{k_m}\ 0{,}07d_p$	$\omega\ \sqrt{k_m}\ 0{,}07d_p$	$\omega\ \sqrt{k_m}\ 0{,}07d_p$
Wall thickness of rectangular pillars	$\omega\ \sqrt{k_m}\ 0{,}07b_p$	$\omega\ \sqrt{k_m}\ 0{,}07b_p$	$\omega\ \sqrt{k_m}\ 0{,}07b_p$

Symbols

ω = service type correction factor as determined from Table 3.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R is as defined in 1.5.1.

Table 3.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

2.3 Impact considerations

2.3.1 Due consideration is to be given to the scantlings of all structure which may be subject to local impact loadings. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion e.g. passenger routes, working areas of fishing craft, forefoot region etc, are to suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.5 Operation in ice

2.5.1 The minimum plating thickness of craft intended for operation in ice conditions is to comply with Ch 5,7.

■ *Section 3* Shell envelope plating

3.1 General

3.1.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Plate keel

3.2.1 The breadth, b_k, and thickness, t_k, of the plate keel are not to be taken as less than:

$$b_k = 7{,}0L_R + 340 \text{ mm}$$
$$t_k = 1{,}85 \sqrt{k_a}\ L_R^{0{,}45} \text{ mm}$$

where L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the plate keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of the plate keel are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.2.5 For bar keels, *see* 5.2.2.

3.3 Plate stem

3.3.1 The thickness of plate stems, t_s, is not to be taken as less than:

$$t_s = \sqrt{k_a}\ (0{,}14L_R + 4) \text{ mm}$$

L_R and k_a are as defined in 1.5.1.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent shell plating.

3.3.3 Plate stems are to be supported by horizontal diaphragms, and where the stem radius is large, a centreline stiffener or web may be required. Where this is impracticable due to fabrication access considerations, alternative supporting arrangements will be specially considered

3.3.4 For large or novel craft the scantlings of the stem will be specially considered.

3.3.5 The breadth of plate stems is to be not less than the width of keel as required by 3.2.1.

3.4 Bottom shell plating

3.4.1 The thickness of the bottom shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types the minimum thickness requirement for bottom shell plating as, detailed in Section 2, is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater. *See* Fig. 3.3.1.

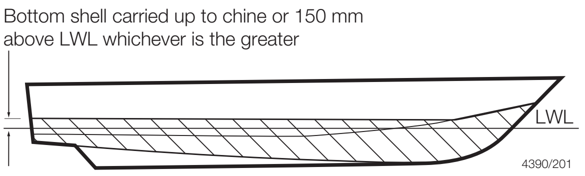


Fig. 3.3.1 Extent of bottom shell

3.5 Side shell plating

3.5.1 The thickness of the side shell plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Sheerstrake

3.6.1 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by or be greater than those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.18.2 and 4.18.3 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, then the strengthening arrangements are to be increased accordingly.

3.6.5 For pilot craft which may be subject to repeated impact loadings from contact with other craft etc., the sheerstrake plating is to be increased locally by not less than 50 per cent of the side shell thickness. The increased thickness is to extend from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point which the deckline reaches its greatest breadth whichever is the greater and forward of the quarter and over the transom for a distance of $0{,}075L_R$ or 1,0 m, whichever is the greater. It is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height whichever is the greater. The additional thickness is then to be tapered out to the side shell thickness in accordance with the Rules.

3.6.6 Fishing craft are in general to have their shell plating scantling as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken less than as bottom shell thickness, and where there are gallows, gantries, nets, or lines etc. the plating in way is to be further increased locally and/or suitably protected by sheathing or other means.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted.

3.6.8 Where a rounded sheerstrake is adopted the radius, in general, is to be not less than 15 times the thickness.

3.6.9 The sheerstrake thickness is to be increased by 20 per cent at the ends of a bridge superstructure extending out to the craft's side. In the case of a bridge superstructure exceeding $0{,}15L_R$, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the upper deck sheerstrake.

3.6.10 In general, compensation will not be required for openings in the sheerstrake which are clear of the gunwale or deck openings and whose depth does not exceed 20 per cent of the depth of the sheerstrake. Openings are not to be cut in a rounded gunwale.

3.7 Chines

3.7.1 The chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

3.7.2 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

3.7.3 Full penetration welding of shell plating in way of chines is always to be maintained.

3.7.4 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration. *See also* LR's *Guidance Notes for Structural Details*.

3.8 Skegs

3.8.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell and additionally is to satisfy the requirements for sole pieces given in Ch 3,3 of the Rules for Materials.

3.9 Transom

3.9.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.10 Fin and tuck

3.10.1 The thickness of the plating is to be increased locally in way of the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels.

3.10.2 The plating thickness is to be not less than 1,25 times the thickness of the adjacent shell plating but need not be greater than the plate keel thickness as required by 3.2.

3.11 Shell openings

3.11.1 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings.

3.11.2 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be cut clear of weld connections.

3.12 Sea inlet boxes

3.12.1 The thickness of the sea inlet box plating is to be 1 mm thicker than the adjacent shell plating, or 8 mm, whichever is the greater.

3.13 Local reinforcement/insert plates

3.13.1 The thickness of the shell envelope plating determined in accordance with 3.4 and 3.5 is to be increased locally, by generally not less than 50 per cent in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes and anchor recess. Details of such reinforcement are to be submitted for approval.

3.13.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also* Ch 2,4.21.

3.14 Appendages

3.14.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but in no case are to be taken as less than that of the surrounding structure.

3.15 Fender attachment

3.15.1 Wood belting and fenders are to be bolted to lugs welded to a ground bar attached to the shell and not through-bolted to the shell plating.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are to be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 4*
Shell envelope framing

4.1 General

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.1.2 For each stiffening member an assumed load model is stated. Where the proposed stiffener arrangement differs from that assumed, consideration will be given to an alternative load model.

4.1.3 The geometric properties of stiffener sections are to be in accordance with 1.18.

4.2 Bottom longitudinal stiffeners

4.2.1 Bottom longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.3 Bottom longitudinal primary stiffeners

4.3.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.4 Bottom transverse stiffeners

4.4.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.5 Bottom transverse frames

4.5.1 Bottom transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.6 Bottom transverse web frames

4.6.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the bottom transverse web frames in way of longitudinal primary girders bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.7 Side longitudinal stiffeners

4.7.1 The side longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.7.2 Side longitudinals are to be continuous through the supporting structures.

4.7.3 Where it is impracticable to comply with the requirements of 4.7.2, or where it is proposed to terminate the side longitudinal in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.7.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.8 Side longitudinal primary stiffeners

4.8.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.8.2 Side longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.8.3 Where it is impracticable to comply with the requirements of 4.8.2, or where it is proposed to terminate the side longitudinally in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.9 Side transverse stiffeners

4.9.1 Side transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.9.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

4.10 Side transverse frames

4.10.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.10.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.11 Side transverse web frames

4.11.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinally. They are to be continuous and substantially bracketed at their head and heel connections to deck transverses and bottom web frames respectively.

4.11.2 Where it is impracticable to comply with the requirements of 4.11.1, or where it is proposed to terminate the web frames in way of side longitudinal primary stiffeners bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.11.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

4.12 Grouped frames

4.12.1 For the purposes of satisfying Rule scantling requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of the section moduli and inertia for the group of frames is not to be less than the summation of the Rule requirement for the individual framing members. In addition, in no case is the proposed scantling of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.13 Grillage structures

4.13.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

4.13.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.13.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.14 Combined framing systems

4.14.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.13.

4.15 Floating framing systems

4.15.1 Floating framing systems, where proposed, will be subject to special consideration.

4.16 Frame struts

4.16.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads, the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived above.

4.16.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum cross-sectional area of the strut derived in 4.16.1. To achieve this full penetration welding may be required. The weld connections between the face flats and webs of the pillar supporting structure are to be welded using double continuous welding of an equivalent area to that derived by 4.16.1.

4.17 Arrangements and details

4.17.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

4.17.2 The web stability, openings in the web and continuity and alignment are to be in accordance with 1.24, 1.25 and 1.26 respectively.

4.17.3 Secondary and primary end connections and arrangements at intersection of continuous secondary and primary members are to be in accordance with 1.20, 1.22 and 1.28 respectively.

4.17.4 Stiffeners in slamming areas are to be lugged or bracketed.

4.18 Structure in way of fenders

4.18.1 For craft, including pilot craft and fishing craft, which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of fenders. Details of anticipated loadings and calculations for the required increased scantlings are to be submitted, *see also* 3.6.3 and 3.6.4.

4.18.2 **Pilot craft** are to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6. The knees are to be aligned between the transverse frames and the deck beams. In the case of longitudinally framed craft, intermediate knees are to be fitted with a spacing in general not greater than 500 mm. Where such intermediate brackets are fitted they are to terminate on a side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing, and a deck longitudinal. The side longitudinal is to be positioned below any fendering to carry the heel of the knee. Consideration will given to the termination of such brackets by use of a 'soft-toe' in way of the deck. The thickness of the webs for these knees is to be twice that required by 1.21.

4.18.3 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees, substantial fendering/ rubbing strakes.

4.19 Novel features

4.19.1 The scantlings are to be determined by direct calculation where the shell framing is of unusual design, form or proportions.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction in association with transverse and longitudinal framing systems.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

5.1.4 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The scantlings of the single bottom structure are to comply with the appropriate minimum requirements given in Section 2.

5.2 Keel

5.2.1 The breadth, and thickness of plate keels are to comply with the requirements of 3.2.

5.2.2 The cross-sectional area, A_k, and thickness, t_k, of bar keels are not, in general, be taken as less than:

$$A_k = k_a(1{,}85L_R + 2) \text{ cm}^2$$
$$t_k = \sqrt{k_a}\,(0{,}7L_R + 8{,}25) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3 Centre girder

5.3.1 A centreline girder is, in general, to be fitted throughout the length of the hull in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders are to be formed of intercostal or continuous plate webs with a face flat welded to the upper edge. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement will be required to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, is to be taken not less than:

$$t_w = 1,4\sqrt{k_a}\left(\sqrt{L_R} + 1\right) \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.3.5 The geometric properties of the centre girder are to be in accordance with 1.18.

5.3.6 The face flat area of the centre girder, A_f, is to be not less than:

$$A_f = 0,56 L_R k_a \text{ cm}^2.$$

5.3.7 The face flat area of the centre girder outside $0,5L_R$ amidships may be 80 per cent of the value given in 5.3.6.

5.3.8 The face flat thickness is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but should not exceed 16.

5.3.10 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 6,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness of side girders is to be taken as not less than:

$$t_w = 1,4\sqrt{k_a L_R} \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in 7.3 and 7.5 respectively.

5.4.5 In the engineroom, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

5.5 Floors general

5.5.1 In transversely framed craft, plate floors are generally to be fitted at each frame.

5.5.2 In longitudinally framed craft, plate floors are to be fitted at every transverse web and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are in general to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft forward.

5.5.3 The overall depth, d_f, of plate floors at the centreline is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40(B + 0,85D)$ mm

when $B \geq 10$ m $\quad d_f = 40(1,5B + 0,85D) - 200$ mm

where

D is defined in Pt 3, Ch 1,6.2.8.

5.5.4 The web thickness, t_w, of plate floors, is to be accordance with 1.18 and is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\frac{4,7d_f}{1000} + 3,1\right)\left(\frac{s}{1000} + 0,5\right) \text{ mm}$$

where

d_f is to be determined from 5.5.3

k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area of floors, A_f, is not to be taken as less than:

$$A_f = 0,28 k_a L_R \text{ cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally the requirements of 4.6 for bottom transverse web frames are to be complied with.

5.5.9 Floors are generally to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide effective support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.3 and 7.5.

5.6 Floors in machinery spaces

5.6.1 The thickness, t_w, of the floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength, *see also* 4.12.

5.7 Machinery seatings

5.7.1 The general requirements for machinery seatings are given in Pt 3, Ch 2,6.9, *see also* Pt 9, Ch 1,5.

5.7.2 Engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.7.3 Welding in way of machinery seatings is to be double continuous and/or full penetration where appropriate.

5.8 Drainholes in bottom structure

5.8.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.8.2 Particular attention is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

5.8.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

5.9 Rudder horns

5.9.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by 3.2.

5.9.2 The scantlings of the rudder horn are to be such that the section modulus against transverse bending at any horizontal section XX (*see* Fig. 3.5.1) is not less than:

$$Z = 2{,}8 k_a R_A K_V (V + 3)^2 \sqrt{a^2 + 0{,}5b^2} \quad \text{cm}^3$$

where

R_A = total rudder area, in m^2

V = Maximum speed in the fully loaded condition, in knots

K_V = 1,0 for displacement craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$

= $(1{,}12 - 0{,}005V)^3$ for planing and semi-planing craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$

a, b = dimensions, in metres, as given in Fig. 3.5.1

L_{WL} = waterline length as defined in Pt 3, Ch 1,6.2.5.

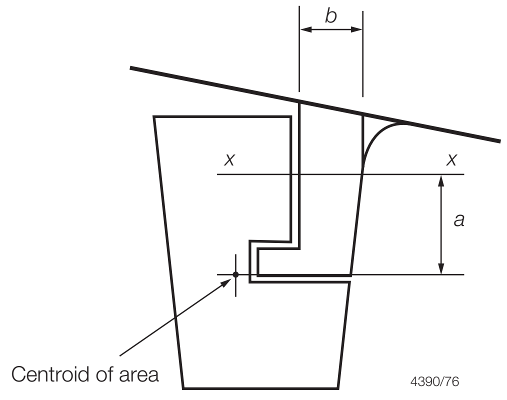


Fig. 3.5.1 Rudder horn

5.9.3 Rudder horns are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.10 Sternframes

5.10.1 The scantlings of fabricated and forged/solid stern-frames are to comply with the requirements of Pt 3, Ch 3,3 modified for appropriate grade of aluminium in accordance with Pt 3, Ch 3,1.2.

5.11 Skeg construction

5.11.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this.

5.11.2 The scantlings and arrangements for skegs (solepieces) are to be in accordance with Pt 3, Ch 3,3.14.

5.11.3 The scantlings of skegs are to be sufficient to with-stand any docking forces that they may be subjected to.

5.12 Forefoot and stem

5.12.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.12.2 The forefoot and stem is to be additionally reinforced with floors.

5.12.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than:

$$A_{bs} = 1,5 k_a L_R \text{ cm}^2$$

where

L_R and k_a are as defined in 1.5.1.

5.13 Transom knee

5.13.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat of the girders may be gradually reduced to that of the transom stiffening members in accordance with Fig. 3.5.2.

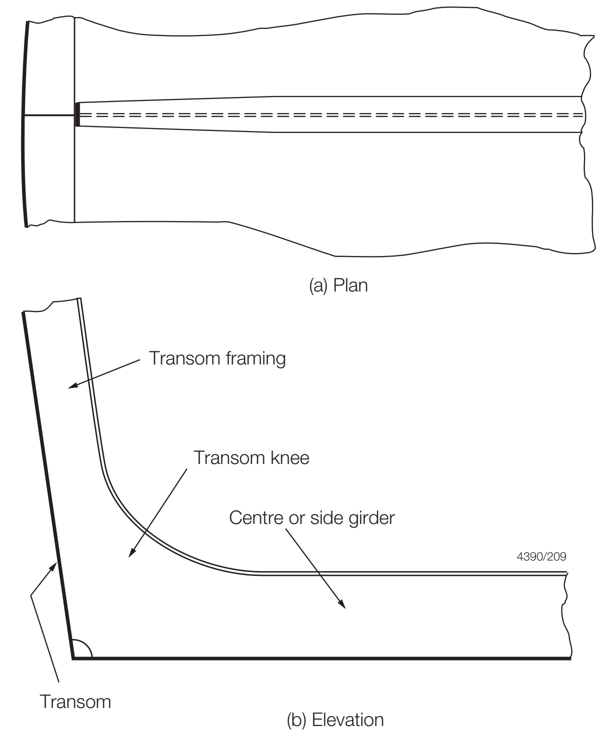


Fig. 3.5.2 Transom knee

5.13.2 Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted loads.

Section 6
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of aluminium mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Double bottoms are generally to be fitted in accordance with Pt 3, Ch 2,6.6 and where fitted are to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable within the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.1.5 The scantlings of the double bottom structure are to comply with the appropriate minimum requirements given in Section 2.

6.2 Keel

6.2.1 The scantlings of bar and plate keels are to comply with the requirements of 5.3.

6.2.2 Duct keels, where arranged, are to have a side plate thickness not less than:

$$t = \sqrt{k_a}\ (0,01 d_{DB} + 2) \text{ mm}$$

but need not be taken as greater than 90 per cent of the centre girder thickness given in 6.3.

d_{DB} is the Rule centre girder depth given in 6.3.3
k_a is as defined in 1.5.1.

6.2.3 Where a duct keel forms the boundary of a tank, the requirements of 7.4 and 7.5 for deep tanks are to be complied with.

6.2.4 The duct keel width is in general to be 15 per cent of the beam or 2 m, whichever is the lesser, but in no case is it to be taken as less than 630 mm. The inner bottom and bottom shell within the duct keel are to be suitably stiffened with primary stiffening in the transverse direction, whilst the continuity of the floors is maintained. Access to the duct keel is to be by means of watertight manholes or trunks.

6.3 Centre girder

6.3.1 A centre girder is to be fitted throughout the length of the craft. The web thickness, t_w, is not to be less than that required by:

$t_w = \sqrt{k_a}\,(0{,}14L_R + 4)$ mm within $0{,}4L_R$ amidships

$= \sqrt{k_a}\,(0{,}14\,L_R + 2{,}75)$ mm at ends.

where

k_a and L_R are as defined in 1.5.1.

6.3.2 The geometric properties of the girder section are to be in accordance with 1.18.

6.3.3 The overall depth of the centre girder, d_{DB}, is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 6,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m.

6.4.3 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 Additionally, the requirements of 4.3 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness of non-watertight plate floors, t_w, is to be not less than:

$t_w = \sqrt{k_a}\,(0{,}07L_R + 4{,}75)$ mm

where

k_a and L are as defined in 1.5.1.

6.5.2 Additionally, the requirements of 4.6 for bottom transverse web frames stiffeners are to be complied with.

6.5.3 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.4 In longitudinally framed craft, plate floors or equivalent structure are in general to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.5 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.6 In transversely framed craft, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Bracket floors

6.6.1 Between plate floors, the shell and inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

6.6.2 In longitudinally framed craft, the brackets are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken as not less than 75 per cent of the depth of the centre girder. They are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.6.3 In transversely framed craft, the breadth of the brackets, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in 6.5.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.5 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors given in 6.5.

6.9 Inner bottom plating

6.9.1 The thickness of the inner bottom plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

6.9.2 Inner bottom plating forming the boundaries of tank spaces is, in addition, to comply with the requirements for watertight bulkheads or deeptanks as detailed in 7.2 or 7.4 respectively. Where the plating forms vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.3 Inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads or other primary structure, generally spaced not more than 2 m apart.

6.9.4 The inner bottom longitudinals are to be continuous through the supporting structure and are to be satisfactorily stiffened against buckling.

6.9.5 Where it is impracticable to comply with the requirements of 6.9.4, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.9.6 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b).

6.10 Inner bottom transverse web framing

6.10.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and to be substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.10.2 Where it is impracticable to comply with the requirements of 6.10.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

6.10.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

6.11 Margin plates

6.11.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

6.12 Wells

6.12.1 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.13 Transmission of pillar loads

6.13.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.14 Manholes

6.14.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. The size of the manhole openings is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.15 Pressure testing

6.15.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

6.16 Drainholes in bottom structure

6.16.1 Sufficient limber holes are to be cut in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

6.16.2 Particular care is to be given to the positioning of limber holes to ensure adequate drainage and to avoid stress concentrations.

6.16.3 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes.

■ *Section 7* **Bulkheads**

7.1 General

7.1.1 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent support and alignment are provided.

7.1.2 The number and disposition of transverse watertight bulkheads are to be in accordance with Pt 3, Ch 2,4.

7.1.3 Bulkheads, or part bulkheads, forming the boundary of tanks are to comply with the requirements of 7.5 and 7.6.

7.1.4 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

7.1.5 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of 7.5 and 7.6 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.13 for washplates.

7.1.6 The minimum requirements in Section 2 are to be complied with.

7.2 Watertight bulkhead plating

7.2.1 The thickness of the watertight bulkhead plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5 Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.3 Watertight bulkhead stiffening

7.3.1 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 using the appropriate load model.

7.3.2 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4 Deep tank plating

7.4.1 The thickness of deep tank plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

7.5 Deep tank stiffening

7.5.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener.

7.5.2 The Rule requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for load model (b).

7.6 Double bottom tanks

7.6.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in 7.4 and 7.5.

7.6.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are to be complied with.

7.7 Collision bulkheads

7.7.1 The scantlings of collision bulkheads are to comply with the requirements of 7.2 and 7.3 except that the thickness of plating and modulus of stiffeners are not to be less than 12 and 25 per cent greater respectively, than required by 7.2 and 7.3. If the collision bulkhead forms the boundary of a deep tank or cofferdam then the requirements of 7.4 and 7.5 are also to be complied with.

7.8 Gastight bulkheads

7.8.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4 the scantling requirements for watertight bulkheads are to be complied with.

7.8.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery exhaust and fuel systems.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of classification.

7.10 Transmission of pillar loads

7.10.1 Bulkheads that are required to act as pillars in way of underdeck girders and other structures subject to heavy loads are to comply with the requirements of Section 10.

7.11 Corrugated bulkheads

7.11.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as s_C, as defined in Fig. 2.3.1 in Pt 3, Ch 2.

7.11.2 In addition, the section geometric properties of 1.18 are to be complied with.

7.11.3 The actual section modulus may be derived in accordance with Pt 3, Ch 2,3.2.

7.12 Stiffeners passing through bulkheads

7.12.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.12.2 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.13 Wash plates

7.13.1 Tanks are to be subdivided as necessary by internal baffles or wash plates. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.13.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.13.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.13.4 The general stiffener requirements are to be in accordance with 7.5. However, the section modulus may be 50 per cent of that required by 7.5.

7.14 Cofferdams

7.14.1 A cofferdam is to be fitted between freshwater and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

7.15 Coatings

7.15.1 Integral freshwater and oil fuel tanks need not in general be coated provided they are constructed from suitable marine grade aluminium alloys in accordance with Chapter 8 of the Rules for Materials. Where tanks are to be coated, then all surfaces are to be cleaned and dried after testing and then treated with a suitable coating in accordance with the coating manufacturer's recommendations. *See* Ch 2,2.6.

7.16 Air pipes

7.16.1 Air pipes of sufficient number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.17 Fire protection

7.17.1 Fire protection requirements given in Part 17 are to be complied with.

7.18 Access

7.18.1 Compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft sides, deckheads and bulkheads, etc., must be capable of being removed. Similarly sufficient space must be available below lower decks/soles to provide proper access to the bottom structure. An adequate number of manholes, removable panels etc. are to be provided.

7.18.2 Doors and hatches fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, to be permanently attached and capable of being closed watertight from both sides of the bulkhead. They are to be tested watertight.

7.18.3 Doors and hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, the doors and hatches are to be watertight, as small as practicable and open into the forepaw compartment. Doors in collision bulkheads are to be kept closed at all times while the craft is at sea, *see* Pt 3, Ch 2,4.3.4.

7.18.4 Particular attention is to be given to the design and workmanship of the tanks, and adequate access manholes are to be fitted, *see* Pt 3, Ch 1,7.

7.19 Testing

7.19.1 Deep tanks are to be tested on completion, with a head of water to the top of the overflow, or 1,8 m above the crown of the tank, whichever is the greater, The pressure to which the tanks will be subjected in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck plating is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams. The transverse and deep transverse beams are to align with side main frames and side web frames respectively.

8.1.2 Beams are to be fitted at every frame and bracketed to the frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, derrick posts and deck machinery.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with 1.22 and 1.20, respectively.

8.1.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.1.9 Deck structures subject to concentrated loads, are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as pillars out of line, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.10 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.1.11 The geometric properties of stiffener sections are to be in accordance with 1.18.

8.2 Strength/weather deck plating

8.2.1 The thickness of strength/weather deck plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.2.2 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck. *See also* Part 4.

8.2.3 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.2.4 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted. *See also* 2.4.

8.3 Lower deck/inside deckhouse plating

8.3.1 The thickness of the lower deck/inside deckhouse plating is to be determined from the general plating equation given in 1.16 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.4 Accommodation deck plating

8.4.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their plating requirements determined in accordance with 8.3.

8.5 Cargo deck plating

8.5.1 The thickness of cargo deck plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.5.2 For vehicle decks, the plating thickness is to comply with the requirements of Ch 5,3.

8.6 Decks forming crowns of tanks

8.6.1 Decks forming the crown of tanks are to comply with the requirements for the appropriate deck, and are to be additionally examined for compliance with the requirements for deep tank plating given in 7.4.

8.7 Strength/weather deck stiffening

8.7.1 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck primary stiffening** are to be determined from the general equations given in 1.17, using the design pressure heads from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

8.7.2 The Rule requirements for section modulus, inertia and web area for the **strength/weather deck secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.7.3 Longitudinal framing is, in general, to be adopted at the strength deck outside line of openings, but special consideration will be given to proposals for transverse framing.

8.8 Lower deck/inside deckhouse stiffening

8.8.1 The Rule requirements for section modulus, inertia and web area for lower deck/inside deckhouse stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9 Accommodation deck stiffening

8.9.1 Accommodation decks are in general to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.8.

8.10 Cargo deck stiffening

8.10.1 The Rule requirements for section modulus, inertia and web area for cargo deck stiffening are to be determined from the general equations given in 1.17 using the design pressure head from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1. Primary members are assumed to be load model (a) and secondary members load model (b). However, special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.10.2 In addition, where the cargo comprises wheeled vehicles, the requirements of Ch 5,3 are to be complied with.

8.11 Deck openings

8.11.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used scantlings may be derived from direct calculations.

8.11.2 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates.

8.11.3 The corners of large hatchways in the strength/weather deck within $0,5L_R$ amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one nor greater than 2,5 to one, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

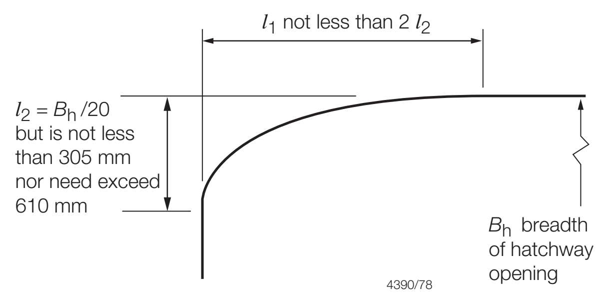


Fig. 3.8.1 Hatch opening geometry

8.11.5 Where the corners are parabolic or elliptical, insert plates are not required.

8.11.6 For other shapes of corner, insert plates of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness, outside line of openings.

8.11.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.11.8 Insert plates will be required at lower decks in way of any rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, insert plates will not normally be required.

8.11.9 Adequate transverse strength is to be provided in the deck area between large hatch openings, subjected to transverse and buckling loads.

8.11.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

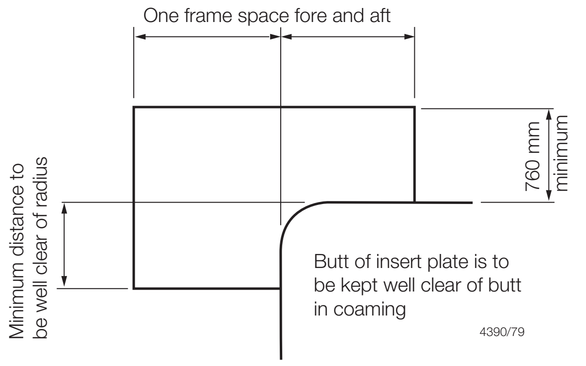


Fig. 3.8.2 Inserts in way of hatch opening

8.12 Sheathing

8.12.1 The requirements for deck sheathing given in 2.4 are to be complied with.

8.13 Novel features

8.13.1 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

■ *Section 9* Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Where practicable, superstructures and deck-houses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.2 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

9.1.5 Structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

9.1.6 The plating thickness of superstructures, deck-houses and bulwarks is in no case to be less than the appropriate minimum requirement given in Section 2.

9.1.7 Stiffener sections and geometric properties are to be in accordance with 1.18.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols applicable to this Section are defined in 1.5.1.

9.3 House side plating

9.3.1 The thickness of house side plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.4 House front plating

9.4.1 The thickness of the house front plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4, 3.1 for non-displacement or displacement craft as appropriate.

9.5 House end plating

9.5.1 The thickness of the house end plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.6 House top plating

9.6.1 The thickness of the house top plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.7 Coachroof plating

9.7.1 The thickness of the coachroof plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.8 Machinery casing plating

9.8.1 The thickness of the plating of machinery casings is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.9 Forecastle requirements

9.9.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. In both cases the plating thickness is to be the same as the side shell plating at deck edge. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

9.9.2 The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

9.9.3 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of 0,25L_R from the F.P. No increase is required if the forecastle end bulkhead lies forward of 0,2L_R from the F.P. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

9.10 House side stiffeners

9.10.1 The Rule requirements for section modulus, inertia and web area for the **house side primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.10.2 The Rule requirements for section modulus, inertia and web area for **house side secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11 House front stiffeners

9.11.1 The Rule requirements for section modulus, inertia and web area for **house front primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.11.2 The Rule requirements for section modulus, inertia and web area for **house front secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for section modulus, inertia and web area for **house aft end primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.12.2 The Rule requirements for section modulus, inertia and web area for **house aft end secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13 House top stiffeners

9.13.1 The house top is to be effectively supported by a system of transverse or longitudinal beams and girders. The span of the beams is in general not to exceed 2,4 m and the beams are to be effectively connected to the house upper coamings and girders.

9.13.2 The Rule requirements for section modulus, inertia and web area for **house top primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.13.3 The Rule requirements for section modulus, inertia and web area for house top **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for section modulus, inertia and web area for coachroof **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.14.2 The Rule requirements for section modulus, inertia and web area for coachroof **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for section modulus, inertia and web area for machinery casing **primary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (a).

9.15.2 The Rule requirements for section modulus, inertia and web area for machinery casing **secondary stiffening** are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.16 Forecastle stiffeners

9.16.1 The scantlings of forecastle primary and secondary stiffening members are to be equivalent to those for the side shell envelope framing at the deck edge as required by Section 4.

9.17 Superstructures formed by extending side structures

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts given in 9.4 and 9.11 for plating and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 The requirements for fire detection, protection and extinction are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in erections. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads, and the upper deck stiffening in way, when large openings for doors and windows are fitted.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of erections within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which can occur in these areas.

9.19.4 For closing arrangements and outfit the requirements are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be vertically transmitted by the window frames, adequate shear rigidity is to be verified by direct calculation.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the erection by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of erections is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Connections between the erection and the deck by means of bimetallic joints are to comply with Ch 2,4.28.

9.22.4 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with the requirements of 2.4.

9.24 Erections contributing to longitudinal strength

9.24.1 For craft above 40 m in length, L_R, or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with Ch 6,2.5.

9.24.2 Where 9.17 applies and the first or second tier is regarded as the strength deck according to Ch 6,2.5, the hull upper deck scantlings at the forward and aft ends of the superstructure may need to be increased due to the lesser efficiency of the superstructure tiers at their ends. The scantlings of the side structure in way of these areas may also need to be increased.

9.24.3 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment or structural efficiency may be required.

9.25 Novel features

9.25.1 Direct calculations may be required to determine the plating and stiffener requirements where the house is of unusual design, form or proportions.

9.26 Bulwarks

9.26.1 General requirements for bulwarks are given in Pt 3, Ch 4,8.

9.26.2 The thickness of the bulwark plating is to be determined from the general plating equation given in 1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

9.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in 1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 for the load model (d).

9.26.4 Bulwarks are not to be cut for gangway or other openings near the breaks of superstructures.

9.26.5 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.26.6 Welding of bulwark to the top edge of sheer strake within $0{,}5L_R$ amidship, is generally to be avoided. However, if this arrangement is not practicable welding to the sheerstrake may be accepted if care is taken to minimise any notch effects.

9.26.7 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed from a continuation of the side shell plating or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the plate thickness of the bulwark is not to be less than the sheerstrake plating thickness. In no case is the thickness of the bulwark plating to be taken as less than 80 per cent of the side shell thickness. The bulwark is to be supported by suitable stiffening members which may be formed from a continuation of the side frames, or from flanged plate stays of the same thickness as the bulwark. In general these frames are to be spaced not more than two side frame spacings apart.

9.26.8 In way of gantries, trawl gallows, mooring pipes, etc., the plate thickness in way is to be increased by not less than 50 per cent.

9.26.9 **Pilot craft** are to be fitted with sufficient hand rails adjacent to the exposed areas of the working decks and platforms. In addition these areas are to have non-skid surfaces.

9.27 Freeing arrangements

9.27.1 Requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.28 Free flow area

9.28.1 The requirements for the free flow area are given in Pt 3, Ch 4,9.3.

9.29 Guard rails

9.29.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

Section 10
Pillars and pillar bulkheads

10.1 Application

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular, or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Determination of span length

10.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by 2/3 the depth of the bracket at each end.

10.3 Head and heel connections

10.3.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

10.4 Alignment and arrangement

10.4.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses and elsewhere where considered necessary.

10.4.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.4.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.4.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets may be used instead of doublers.

10.5 Minimum thickness

10.5.1 The minimum wall thickness of hollow pillars is to be taken as not less than 1/20 of the external dimension of the pillar.

10.6 Design loads

10.6.1 The design loading, P_p, is not to be less than:

$$P_p = S_{gt}\, b_{gt}\, P_c + P_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

10.7 Scantlings determination

10.7.1 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_p = 10\,\frac{P_p}{\sigma_p} \quad \text{cm}^2$$

where

P_p = design load, in kN, supported by the pillar as determined from 10.6

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_p\,\sigma_A}{1 + 0{,}015\sigma_A\, k_f \left(\frac{l_{ep}}{r}\right)^2} \quad \text{N/mm}^2$$

where

f_p = pillar location factor defined in Table 3.10.1

σ_A = 0,2 per cent proof stress of the alloy in the unwelded condition, in N/mm^2

k_f = pillar end fixity factor
= 0,25 for full fixed/bracketed
= 0,50 for partially fixed
= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm, and may be taken as:

$$r = \sqrt{\frac{I_p}{A_p}} \quad \text{cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar or bulkhead, in metres, as defined in 10.2.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.8 Maximum slenderness ratio

10.8.1 The slenderness ratio (l_{ep}/r) of pillars is not to be taken greater than 1,1, where l_{ep} and r are as defined in 10.7.1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

10.9 Pillars in tanks

10.9.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars.

10.9.2 Pillars within tanks are, in general, to be of solid cross section. Where it is proposed to use hollow section pillars each case will be subject to special consideration and the scantlings as determined from the Rules may require to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.9.3 Where pillars within tanks may be subjected to tensile stresses due to hydrostatic pressure, the design is to provide sufficient welding to withstand the tensile load imposed.

10.9.4 Doubling plates at ends of pillars within tanks are not acceptable.

10.10 Pillar bulkheads

10.10.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from 1.11.

10.10.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with 10.7 using the design loading, P_{pb}, as follows:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \text{ kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

S_{bs} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The thickness of the bulkhead plating is in no case to be taken less than 4 mm.

10.11 Direct calculations

10.11.1 As an alternative to 10.6, pillars may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

10.12 Fire aspects

10.12.1 Pillars and pillar bulkheads are to be suitably protected against fire, and, where necessary, be self-extinguishing or capable of resisting fire damage. All pillars are to comply with the requirements of Part 17.

10.13 Novel features

10.13.1 Where unusual or novel pillar designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hulls.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,3.

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
s = stiffener spacing, in mm
t_p = plating thickness, in mm
L_R = Rule length of craft, in metres
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

1.5.2 **Bottom outboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard.** For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck.** The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch.** The haunch is defined as the transition area between the cross-deck and the inboard side shell plating.

1.5.6 **Side inboard.** The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard.** The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck.** The wet-deck is defined as the area between the upper edges of the side inboard plating (or upper edges of the haunches, where fitted).

Section 2
Minimum thickness requirements

2.1 General

2.1.1 Unless otherwise specified in this Section, the requirements of Ch 3,2 are to be complied with.

2.1.2 The thickness of plating and stiffeners determined from the Rule requirements is in no case to be less than the appropriate minimum requirement given in Table 4.2.1 for craft type.

2.1.3 In addition, where plating contributes to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

Table 4.2.1 Minimum thickness requirements

Item	Minimum thickness (mm)		
	Catamaran	Multi-hull	Swath
Shell envelope Bottom shell plating	$\omega\sqrt{k_m}(0{,}7\sqrt{L_R}+1{,}0)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}7\sqrt{L_R}+1{,}0)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}7\sqrt{L_R}+1{,}0)\geq 4{,}0\,\omega$
Side shell plating	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Wet-deck plating	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Single bottom structure Centre girder web	$\omega\sqrt{k_m}(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$
Floor webs	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$
Side girder webs	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$
Double bottom structure Centre girder			
(1) Within 0,4*L* amidships	$\omega\sqrt{k_m}(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}(1{,}1\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$
(2) Outside 0,4*L* amidships	$\omega\sqrt{k_m}(0{,}95\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}95\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}95\sqrt{L_R}+1{,}4)\geq 5{,}0\,\omega$
Floors and side girders	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}8\sqrt{L_R}+1{,}1)\geq 4{,}0\,\omega$
Inner bottom plating	$\omega\sqrt{k_m}(0{,}7\sqrt{L_R}+1{,}3)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}7\sqrt{L_R}+1{,}3)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}7\sqrt{L_R}+1{,}3)\geq 3{,}5\,\omega$
Bulkheads Watertight bulkhead plating	$\omega\sqrt{k_m}(0{,}43\sqrt{L_R}+1{,}2)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}43\sqrt{L_R}+1{,}2)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}43\sqrt{L_R}+1{,}2)\geq 3{,}0\,\omega$
Deep tank bulkhead plating	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Deck plating and stiffeners Strength/Main deck plating	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}5\sqrt{L_R}+1{,}4)\geq 3{,}5\,\omega$
Lower deck/Inside deckhouse	$\omega\sqrt{k_m}(0{,}3\sqrt{L_R}+1{,}3)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}3\sqrt{L_R}+1{,}3)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}3\sqrt{L_R}+1{,}3)\geq 3{,}0\,\omega$
Superstructures and deckhouses Superstructure side plating	$\omega\sqrt{k_m}(0{,}4\sqrt{L_R}+1{,}1)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}4\sqrt{L_R}+1{,}1)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}4\sqrt{L_R}+1{,}1)\geq 3{,}0\,\omega$
Deckhouse front 1st tier	$\omega\sqrt{k_m}(0{,}62\sqrt{L_R}+1{,}8)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}62\sqrt{L_R}+1{,}8)\geq 3{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}62\sqrt{L_R}+1{,}8)\geq 3{,}5\,\omega$
Deckhouse front upper tiers	$\omega\sqrt{k_m}(0{,}55\sqrt{L_R}+1{,}5)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}55\sqrt{L_R}+1{,}5)\geq 3{,}0\,\omega$	$\omega\sqrt{k_m}(0{,}55\sqrt{L_R}+1{,}5)\geq 3{,}0\,\omega$
Deckhouse aft	$\omega\sqrt{k_m}(0{,}25\sqrt{L_R}+0{,}7)\geq 2{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}25\sqrt{L_R}+0{,}7)\geq 2{,}5\,\omega$	$\omega\sqrt{k_m}(0{,}25\sqrt{L_R}+0{,}7)\geq 2{,}5\,\omega$
Pillars Wall thickness of tubular pillars	$\omega\sqrt{k_m}\,0{,}07d_p$	$\omega\sqrt{k_m}\,0{,}07d_p$	$\omega\sqrt{k_m}\,0{,}07d_p$
Wall thickness of rectangular pillars	$\omega\sqrt{k_m}\,0{,}07b_p$	$\omega\sqrt{k_m}\,0{,}07b_p$	$\omega\sqrt{k_m}\,0{,}07b_p$

Symbols

ω = service type factor as determined from Table 4.2.2
k_m = $385/(\sigma_A + \sigma_u)$
σ_A = specified minimum yield stress or 0,2% proof stress of the alloy in unwelded condition, in N/mm^2
σ_u = specified minimum ultimate tensile strength of the alloy in unwelded condition, in N/mm^2
b_p = minimum breadth of cross section of hollow rectangle pillar, in mm
d_p = outside diameter of tubular pillar, in mm
L_R = as defined in 1.5.1

Table 4.2.2 Service type correction factors (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,0
Patrol	1,0
Pilot	1,1
Yacht	1,0
Workboat MFV	1,2

Section 3
Shell envelope plating

3.1 General

3.1.1 Unless otherwise specified within this Section, the scantlings and arrangements for shell envelope plating are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

3.1.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in Section 2.

3.2 Keel plates

3.2.1 The breadth, b_k, and thickness, t_k, of plate keels are not to be taken as less than:

$$b_k = 5{,}0L_R + 250 \text{ mm}$$

$$t_k = \sqrt{k_a}\ 1{,}85L_R^{0{,}45} \text{ mm}$$

where

L_R and k_a are as defined in 1.5.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem.

3.2.4 For large or novel craft and for yachts with externally attached ballast keels, the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 The thickness of the bottom outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.3.2 For all craft types, the minimum bottom outboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4 Bottom inboard

3.4.1 The thickness of the bottom inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.4.2 For all craft types, the minimum bottom inboard shell thickness requirement given in Section 2 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.5 Side outboard

3.5.1 The thickness of the side outboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.6 Side inboard

3.6.1 The thickness of the side inboard plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7 Wet-deck

3.7.1 The thickness of the wet-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.7.2 Additionally, the thickness of the wet-deck plating is in no case to be less than the thickness of the side inboard shell plating determined from 3.6.

3.7.3 The wet-deck plating on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the sheathing requirements given in Ch 3,2.4 are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of the stern or transom are to be not less than that required for the adjacent bottom inboard or side outboard structure as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 40 m in Rule length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when determining the effective breadth of the attached plating.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the thickness of the lower hull shell plating may be derived from an established method for shell analysis or recognised standard for pressure vessels using the design pressure loading from Pt 5, Ch 4,3.1. Other loads considered significant for the scantling determination are to be taken into account. Modes of failure to be considered are buckling, frame collapse, inter-frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for plating elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 4* Shell envelope framing

4.1 General

4.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by, Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 Bottom outboard longitudinal stiffeners are to be supported by transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinals are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is proposed to terminate the bottom outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, all longitudinals are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.2.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 Bottom outboard longitudinal primary stiffeners are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is proposed to terminate the stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.3.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell and which may be continuous or intercostal.

4.4.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell. They are to be effectively continuous and bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals. They are to be continuous and substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is proposed to terminate the web frames in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard stiffening member design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard stiffening design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinals are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.13 Side outboard longitudinal primary stiffeners

4.13.1 Side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is proposed to terminate the side outboard longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members supporting the side shell and may be continuous or intercostal.

4.14.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals. They are to be continuous and substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is proposed to terminate the side outboard longitudinals in way of bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.13 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinals are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.22.5 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken as less than those required for the side inboard longitudinal stiffeners detailed in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 Wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 4 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through transverse bulkheads and supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is proposed to terminate the wet-deck longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.23.4 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.23.5 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken as less than those required for the side inboard longitudinal primary stiffeners detailed in 4.18.

4.23.6 Additionally the requirements of Chapter 6 relating to global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members supporting the wet-deck and may be continuous or intercostal.

4.24.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b).

4.24.3 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken as less than those required for the side inboard transverse stiffeners detailed in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck. They are to be effectively continuous and bracketed at their end connections to side frames.

4.25.2 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.25.3 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken as less than those required for the side inboard transverse frames detailed in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals. They are to be continuous and substantially bracketed at their end connections to side transverse web frames.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is proposed to terminate the wet-deck longitudinals in way of the bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The requirements for section modulus, inertia and web area are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

4.26.4 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken as less than those required for the side inboard transverse web frames detailed in 4.21.

4.26.5 Primary transverse web frames that link the strength deck to the wet-deck structure and which carry the transverse global loading are additionally to comply with Ch 6,3.4.

4.26.6 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the inboard side structure and integrated into transverse bulkheads or other primary structure within each hull (*see* Fig. 4.4.1). In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell plating in way of the intersection is to be increased locally by not less than 50 per cent.

4.27 Lower hull (SWATH)

4.27.1 Where the lower hull structure incorporates ring frames and attached shell plating fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels using the design loading from Pt 5, Ch 4,3.1 Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. A copy of the direct calculations is to be submitted for consideration.

4.28 Scantlings of end brackets

4.28.1 The scantlings of end brackets in way of transverse web frames/crossdeck primary structure which carry transverse global loading, are to be as large as practicable and be additionally reinforced as necessary. The webs of deep brackets are to be stiffened as necessary to resist buckling, *see also* Ch 6,3.5.

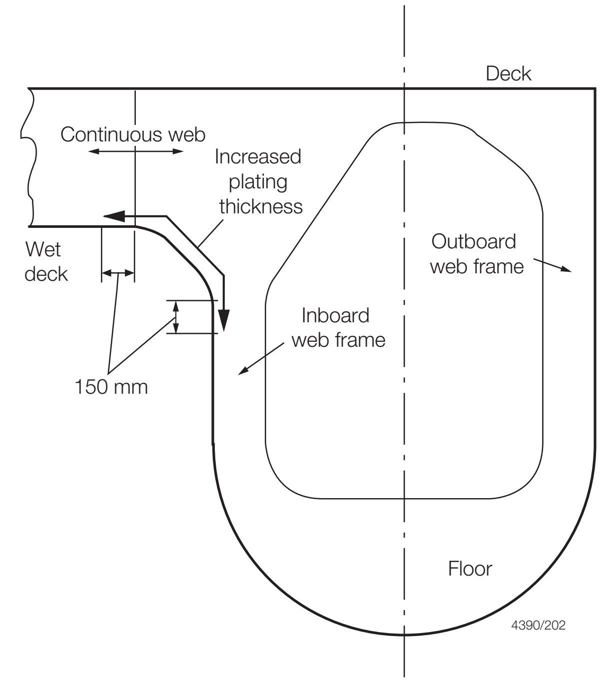


Fig. 4.4.1
End connection details, wet-deck structure

Section 5
Single bottom structure and appendages

5.1 General

5.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by, Ch 3,5 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

5.1.2 The thickness of single bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2.

5.2.2 Where fitted, the cross-sectional area, A_{bk}, and thickness, t_{bk}, of bar keels should not, in general, be taken as less than:

$$A_{bk} = k_a (1{,}85L_R + 2) \text{ cm}^2$$
$$t_{bk} = \sqrt{k_a} (0{,}7L_R + 8{,}25) \text{ mm}$$

where
L_R and k_a are as defined in 1.5.1.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous plate webs. In all cases the face flat is to be continuous. Where girder webs are intercostal, additional bracketing and local reinforcement are to be provided to maintain the continuity of structural strength.

5.3.3 The web depth of the centre girder is, in general, to be equal to the depth of the floors at the centreline as specified in 5.5.3.

5.3.4 The web thickness, t_w, of the centre girder is to be taken as not less than:

$$t_w = \sqrt{k_a}\left(\sqrt{1{,}9L_R} + 1{,}3\right) \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.3.5 The face flat area, A_f, of the centre girder is to be not less than:

$$A_f = 0{,}42k_a L_R \text{ cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

5.3.6 The geometric section properties of the centre girder are to be in accordance with Ch 3,1.18.

5.3.7 The face flat area of the centre girder outside $0{,}5L_R$ may be 80 per cent of the value given in 5.3.5.

5.3.8 The face flat thickness, t_w, is to be not less than the thickness of the web.

5.3.9 The ratio of the width to thickness of the face flat is to be not less than eight but is not to exceed 16.

5.3.10 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4 Side girders

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 2 m. Side girders where fitted are to extend as far forward and aft as practicable and are, in general, to be scarfed into the bottom structure forward and aft of the support at which they terminate, i.e. terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 The web thickness, t_w, of side girders is to be taken as not less than:

$$t_w = \sqrt{0{,}83k_a L_R} \text{ mm}$$

where

k_a and L_R are as defined in 1.5.1.

5.4.3 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in 5.5.6 and 5.5.7.

5.4.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

5.4.5 Watertight side girders, and side girders forming the boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads and deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4 respectively.

5.4.6 In the engine room, additional side girders are generally to be fitted in way of main machinery seatings. Where fitted they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

5.5 Floors general

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are, in general, to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall web depth, d_w, of floors at the centreline, is not to be taken as less than:

$$d_w = 6{,}2L_R + 50 \text{ mm}$$

where

L_R is as defined in 1.5.1.

5.5.4 The web thickness of plate floors, t_w, is to be in accordance with Ch 3,1.18 and not less than:

$$t_w = \sqrt{k_a}\left(\frac{4{,}7d_f}{1000} + 3{,}1\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is determined from 5.5.3 and
k_a and s are as defined in 1.5.1.

5.5.5 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.6 The face flat area, A_f, of floors is not to be taken as less than:

$$A_f = k_a\,0{,}21 L_R \ \text{cm}^2$$

where

k_a and L_R are defined in 1.5.1.

5.5.7 The face flat thickness, t_f, is to be not less than the thickness of the web and the ratio of the web to the thickness of the face flat is to be not less than eight but is not to exceed 16.

5.5.8 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.9 Floors are in general to be continuous from side to side.

5.5.10 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required section modulus.

5.5.11 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.12 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 and Ch 3,7.4.

5.6 Floors in machinery space

5.6.1 The web thickness, t_w, of floors in machinery spaces is to be 1 mm greater than that required by 5.5.4.

5.6.2 The depth and mechanical strength properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The face flat area and web thickness of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength, *see also* Ch 3,4.12.

5.7 Forefoot and stem

5.7.1 The thickness of plate stems at the waterline is to comply with the requirements for plate keels as given in 3.2.

5.7.2 The forefoot and stem are to be additionally reinforced with floors.

5.7.3 The cross-sectional area of bar stems, A_{bs}, is not to be taken as less than :

$$A_{bs} = 1{,}1 k_a L_R \ \text{cm}^2$$

where

k_a and L_R are as defined in 1.5.1.

■ *Section 6* Double bottom structure

6.1 General

6.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for the double bottom structure are to be determined in accordance with the procedures described in, or as required by, Ch 3,6 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

6.1.2 The thickness of double bottom structural members is in no case to be less than the appropriate minimum requirement given in Section 2.

6.2 Keel

6.2.1 The scantlings of plate and bar keels are to comply with the requirements of 5.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, is to be not less than that required by:

$$t_w = \sqrt{k_a}\,(0{,}082 L_R + 4{,}1) \text{ mm within } 0{,}4L \text{ amidships}$$

$$= \sqrt{k_a}\,(0{,}082 L_R + 2{,}7) \text{ mm at ends}$$

where

k_a and L_R are as defined in 1.5.

6.3.2 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.3.3 The overall web depth, d_w, of the centre girder is to be taken as not less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the floor breadth does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of floor is greater than 4,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 2,0 m.

6.4.3 Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to be scarfed into the bottom structure forward and aft of the supporting bulkheads, deep floors or other primary transverse structure.

6.4.4 Where additional side girders are fitted in way of main machinery seatings, they are to be integrated into the structure of the craft and extended forward and aft as far as practicable.

6.4.5 Under the main engine, girders extending from the bottom shell to the top plate of the engine seating are to be fitted. The height of the girders is to be not less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors and/or hanging brackets are to be fitted.

6.4.6 The geometric properties of the girder section are to be in accordance with Ch 3,1.18.

6.4.7 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 The web thickness, t_w, of non-watertight plate floor is to be not less than:

$$t = \sqrt{k_a}\ (0{,}41L_R + 4{,}8)\ \text{mm}$$

where

k_a and L_R are as defined in 1.5.

6.5.2 The geometric properties of the floor section are to be in accordance with Ch 3,1.18.

6.5.3 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.4 Plate floors are, in general, to be continuous between the centre girder and the margin plate.

6.5.5 In longitudinally framed craft, plate floors are to be fitted in the following positions:

(a) At every half frame in way of the main engines, thrust bearings, and bottom of the craft forward.
(b) Outboard of the engine seatings, at every frame within the engine room.
(c) Underneath pillars and bulkheads.
(d) Outside of the engine room at a spacing not exceeding 2,0 m.

6.5.6 Vertical flat bar stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_w$ and a thickness of not less than t_w, where t_w is thickness of the plate floor as calculated in 6.5.1.

6.5.7 In transversely framed craft, plate floors are to be fitted at every frame in the engineroom, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 2,0 m.

6.6 Additional requirements for watertight floors

6.6.1 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.2 or Ch 3,7.4 respectively.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

7.2 Longitudinal bulkheads within the cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be:

- one for catamarans of Rule length, L_R, less than or equal to 24 m;
- two for catamarans of Rule length, L_R, greater than 24 m; and
- four for trimarans.

Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements for cross deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 with regard to global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings of cross deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.2 and Ch 3,7.3 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the plating or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross deck structure may be permitted, provided that the global strength requirements are satisfied. Cut outs through the bulkhead are not to exceed 50 per cent of its depth, *see also* Ch 3,7.18.

7.5.2 Where the cross deck structure acts as a watertight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local reinforcement

7.6.1 Bulkheads forming the cross deck structure are to be suitably strengthened, if necessary, in way of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within the cross-deck structure

7.7.1 Where the cross deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Unless otherwise specified in this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by, Ch 3,8 for mono-hull craft using the pressures from Part 5 appropriate to multi-hulls.

8.2 Arrangements

8.2.1 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2.2 For craft up to 50 m in Rule length, L_R, where the cross-deck is formed by transverse primary stiffeners or bulkheads, and subjected to global transverse loads in accordance with 8.2.1 the scantling requirements to satisfy the global loading condition are given in Ch 6,3.5.

8.2.3 Superstructures fitted on the cross-deck structures, on craft up to 50 m in Rule length, L_R, will, in general, be considered as non-load carrying and are not to be included in the strength of the cross-deck. For designs where the superstructure is designed to absorb global loads, the requirements are given in Ch 6,3.2.

8.2.4 For craft more than 50 m in Rule length, L_R, global analysis is required to determine the response of the deck and superstructure as a system. Deck scantlings may then be derived for compliance with the requirements of Ch 6,3.

8.3 Cross-deck plating

8.3.1 The thickness of the cross-deck plating is to be determined from the general plating equation given in Ch 3,1.16 using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

8.3.2 The thickness of the cross-deck plating is in no case to be less than the appropriate minimum requirement given in Section 2.

8.3.3 The scantlings of watertight cockpits are to be of equivalent strength to those of the strength/weather deck, *see also* Part 4.

8.3.4 It is recommended that the working areas of the weather deck have an anti-slip surface.

8.3.5 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.4.

8.4 Cross-deck stiffening

8.4.1 The Rule requirements for section modulus, inertia and web area for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (a).

8.4.2 The Rule requirements for section modulus, inertia and web area of the strength/weather deck secondary stiffening are to be determined from the general equations given in Ch 3,1.17, using the design pressures from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate, and the coefficients Φ_Z, Φ_I, and Φ_A as detailed in Table 3.1.1 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.4.3 The geometric properties of stiffener sections are to be in accordance with Ch 3,1.18.

8.4.4 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may require increasing appropriately.

8.4.5 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Ch 7,2 and Ch 7,3.

8.4.6 Where stiffening members support plating of the extruded plank type, or the floating frame system is used, the plating is not to be included in the scantling derivation of the supporting structure.

8.4.7 Openings in the cross-deck for hatches, etc., are to comply with the requirements of Ch 3,8.11.

8.5 Novel features

8.5.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation and a copy is to be submitted for consideration.

■ *Section 9*
Superstructures, deckhouses, pillars and bulwarks

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required by, Ch 3,9 for mono-hull craft.

9.1.2 The scantlings and arrangements for pillars and pillar bulkheads are to be determined in accordance with the procedures described in, or as required by, Ch 3,10 for mono-hull craft.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

k_a = alloy factor
= $125/\sigma_a$
s = stiffener spacing, in mm
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys are to be of suitable marine grades in accordance with the requirements of Ch 2,2.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.10 For details of machinery requirements, *see* Pt 12, Ch 2.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will require to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment and the structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation calculations are to be submitted to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are to be contained within a watertight compartment.

2.3.7 Foils attached by riveted means are in addition to comply with Ch 2,4.25.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and comply with Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.7.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure and are to include a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom plating in way is to be not less than 1,5 times the thickness of the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means and proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The plating thickness in way of integral scoops is to be not less than 1,5 times the thickness of the adjacent shell plating, with additional reinforcement at the leading edge.

2.5.6 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include design calculations covering the parameters indicated in 2.6.2.

2.6.5 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

2.6.6 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) cushion pressure;

(b) calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery and is to be suitably reinforced by the use of backing plates.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable with a fastener spacing of not more than 50 mm.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted hull connection of the preform to the hull structure is considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tabs are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.

(b) Details and calculations of the hull attachment.

(c) Details and calculations of the local internal reinforcement in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails may be integrated into the hull structure or added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a plating thickness not less than the adjacent bottom shell and additionally have a section modulus and inertia equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached by double continuous welding and are additionally to comply with the strength requirements of 2.9.2.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary.

2.9.5 In no case are the toes of spray rails to terminate on unsupported plating.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the plating thickness in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation are outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3*
Vehicle decks

3.1 General

3.1.1 These requirements are applicable to longitudinally or transversely framed craft intended for the carriage of wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

3.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

3.2 Definitions

3.2.1 **Load area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

3.3 Deck plating

3.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1370\sqrt{k_a}} \text{ mm}$$

where

P_1 = corrected patch load, in tonnes, obtained from Table 5.3.1
α = thickness coefficient obtained from Fig. 5.3.1
s = secondary stiffener spacing, in mm
β_p = tyre print coefficient used in Fig. 5.3.1
$= \log_{10}\left(\frac{3{,}5 P_1\, k_a^2}{s^2} \times 10^7\right)$

s and k_a are as defined in 1.2.

Table 5.3.1 Deck plate thickness calculation

Symbols	Expression	
a, s, u, and v as defined in Fig. 5.3.1	$P_1 = \phi_1\ \phi_2\ \phi_3\ \lambda\ P_w$	
n = tyre correction factor as detailed in Table 5.3.2	$\phi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$	$v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
P_1 = corrected patch load, in tonnes	$\phi_2 = 1{,}0$	for $u \leq (a - s)$
λ = dynamic magnification factor	$= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$	for $a \geq u > (a - s)$
P_w = load, in tonnes, on the tyre print. For closely spaced wheels the shaded area shown in Fig. 5.3.1 may be taken as the combined print	$= 0{,}77\ \dfrac{a}{u}$	for $u > a$
λ = dynamic magnification factor	$\phi_3 = 1{,}0$	for $v < s$
ϕ_1 = patch aspect ratio correction factor	$= 0{,}6\ (s/v) + 0{,}4$	for $1{,}5 > (v/s) > 1{,}0$
ϕ_2 = panel aspect ratio correction factor	$= 1{,}2\ (s/v)$	for $(v/s) \geq 1{,}5$
ϕ_3 = wide patch load factor	$\lambda = 1{,}25$ for craft operating in G1 $= (1 + 0{,}35n)$ for craft operating in G2 $= (1 + 0{,}42n)$ for craft operating in G3 $= (1 + 0{,}49n)$ for craft operating in G4 $= (1 + 0{,}56n)$ for craft operating in G5 $= (1 + 0{,}70n)$ for craft operating in G6 G1, G2, G3, G4, G5 and G6 as defined in Pt 1, Ch 2,3.5.5	

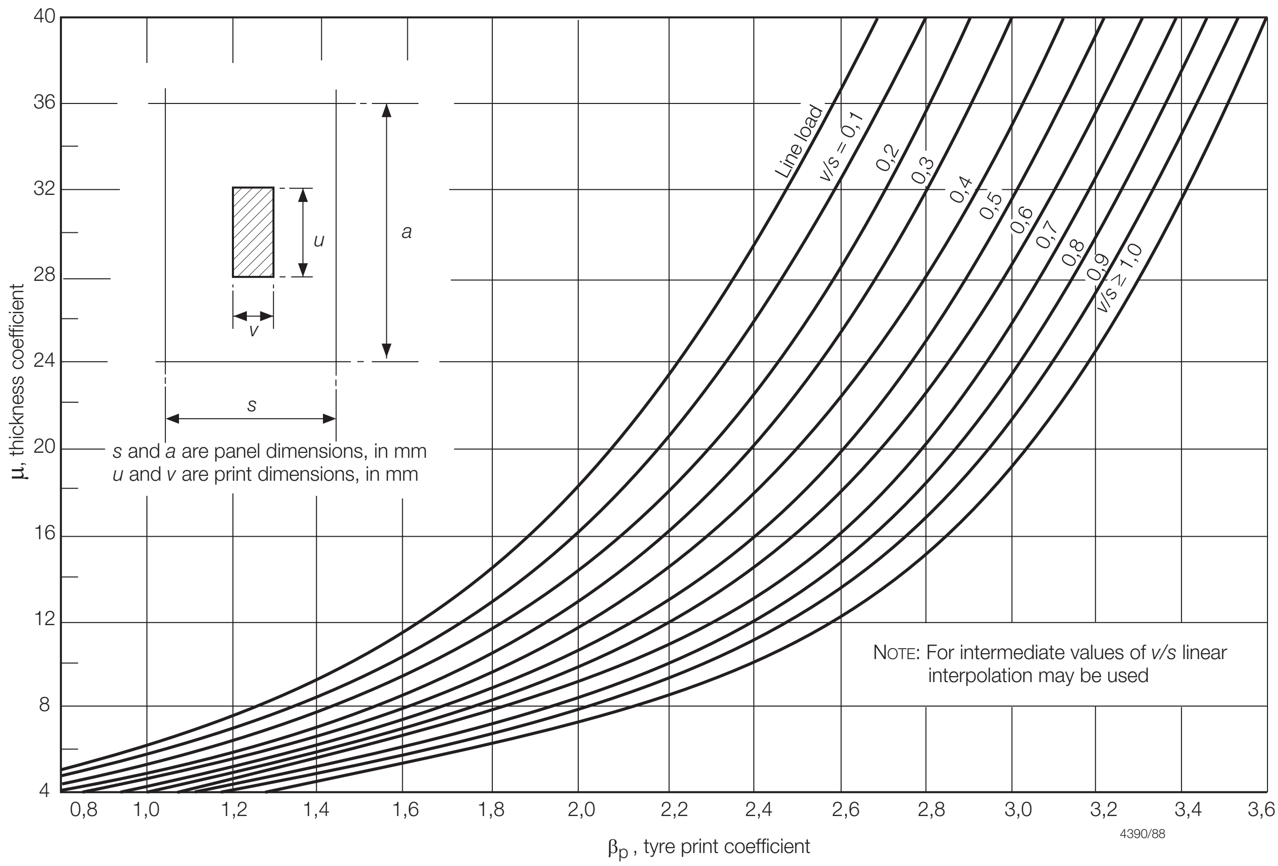


Fig. 5.3.1 Tyre print chart

3.4 Secondary stiffening

3.4.1 The scantlings of vehicle deck stiffeners are to be as required to satisfy the most severe arrangement of print wheel loads in conjunction with the cargo/weather deck design head.

3.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with Table 5.3.3, *see also* Fig. 5.3.1 and Table 5.3.2.

Table 5.3.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, n	Solid rubber tyres correction factor, n
1	0,6	0,8
2 or more	0,75	0,9

3.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

3.4.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with Table 7.3.1 in Chapter 7.

3.5 Primary stiffening

3.5.1 The scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the limiting permissible stress and deflection criteria contained in Chapter 7.

3.6 Securing arrangements

3.6.1 Details of the connections to the hull of vehicle securing arrangements are to be submitted for approval.

3.6.2 Deck fittings in way of vehicle lanes are to be recessed.

3.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

Table 5.3.3 Secondary stiffener requirements

Scantling requirement	Load case $d \leq l$	Load case $d > l$
Section modulus (Z) (cm^3)	$Z = \left(\dfrac{P\ k_w\ (3l^2 - d^2)}{24\ l\ f_\sigma\ \sigma_a}\right) \times 10^3 + Z_{dk}$	$Z = \left(\dfrac{k_w\ P\ l^2}{10\ d\ f_\sigma\ \sigma_a}\right) \times 10^3 + Z_{dk}$
Inertia (I) (cm^4)	$I = \left(\dfrac{f_\delta\ P\ k_w\ (2l^3 - 2d^2\ l + d^3)}{384\ E\ l}\right) \times 10^5 + I_{dk}$	$I = \left(\dfrac{f_\delta\ k_w\ P\ l^3}{384\ E\ d}\right) \times 10^5 + I_{dk}$
Web area (A_W) (cm^2)	$A_W = \dfrac{10P\ k_w\ (m^3 - 2m^2 + 2)}{2\ f_\tau\ \tau_a} + A_{dk}$ where $m = d/l$	$A_W = \dfrac{k_w\ P\ l}{2\ d\ f_\tau\ \tau_a} + A_{dk}$

Symbols

P = maximum effective load per wheel or group of wheels, in kN
l = overall secondary stiffener length, in metres
s = stiffener spacing, in metres
d = dimension of load area parallel to stiffener axis, in metres
E = Young's modulus of elasticity of material, in N/mm^2
w = dimension of load area perpendicular to stiffener axis, in metres
k_w = lateral loading factor
= 1 for $w \leq s$
= s/w for $w > s$
f_σ = limiting bending stress coefficient taken from Table 7.3.1 in Chapter 7
f_τ = limiting shear stress coefficient taken from Table 7.3.1 in Chapter 7
f_δ = limiting deflection coefficient taken from Table 7.2.1 in Chapter 7
σ_a = 0,2% proof stress of material, in N/mm^2
τ_a = shear stress of the alloy, in N/mm^2
= $\dfrac{\sigma_a}{\sqrt{3}}$
Z_{dk}, I_{dk}, A_{dk} = stiffener requirements for weather/cargo decks to be determined in accordance with Ch 3,8.7 and Ch 3,8.10 using the appropriate design head for weather/cargo. In no case is the head to be taken as less than 2 kN/m^2

3.7 Access

3.7.1 Bow doors are to comply with the requirements of Section 4.

3.7.2 Where access to the vehicle deck is provided by side and stern doors the doors are to have scantlings equivalent to the structure in which they are fitted, *see also* Pt 3, Ch 4,4.

3.7.3 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the requirements of Part 17.

3.8 Hatch covers

3.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage model. A copy of the calculations is to be submitted.

3.9 Heavy and special loads

3.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.9.2 Due account is to be taken of the acceleration levels due to craft motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.10 Direct calculations

3.10.1 LR will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Bow doors

4.1 Application

4.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure.

4.1.2 Other types of bow door will be specially considered.

4.2 General

4.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be imposed by the National Authority.

4.2.2 Bow doors are to be situated above the freeboard deck. A watertight recess in the freeboard deck located forward of the collision bulkhead and above the deepest waterline fitted for arrangement of ramps or other related mechanical devices may be regarded as a part of the freeboard deck.

4.2.3 An inner door is to be fitted. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see* Pt 3, Ch 2,4. A vehicle ramp may be arranged for this purpose, provided its position complies with Pt 3, Ch 2,4 and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the freeboard deck may extend forward of the limit specified in Pt 3, Ch 2,4. If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

4.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the cargo space and arranged with fixed sealing supports on the aft side of the doors.

4.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in 4.2.3.

4.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

4.3 Symbols and definitions

4.3.1 The symbols used in this Section are defined as follows:

a_{bv} = vertical distance, in m, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in Fig. 5.4.2

b_{bv} = horizontal distance, in m, from visor pivot to the centroid of the horizontal projected are of the visor door, as shown in Fig. 5.4.2

c_{bv} = horizontal distance, in m, from visor pivot to the centre of gravity of visor mass, as shown in Fig. 5.4.2

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in Fig. 5.4.1

k_a = alloy factor
= $125/\sigma_a$

l_d = length of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.2

A_s = area stiffener web in cm^2

A_x = area, in m^2, of the transverse vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser, as shown in Fig. 5.4.2

A_y = area, in m^2, of the longitudinal vertical projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, whichever is the lesser

A_z = area of the horizontal projection of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in m^2, whichever is the lesser, as shown in Fig. 5.4.2

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in 4.5.1

W = breadth of the door at a height $h/2$ above the bottom of the door, in metres, as shown in Fig. 5.4.1

W_{bv} = mass of the visor door, in tonnes

σ = bending stress, in N/mm^2

σ_a = material yield stress, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2
= $\sqrt{\sigma^2 + 3\tau^2}$

τ = shear stress, in N/mm^2.

4.3.2 **Locking device.** A device that locks a securing device in the closed position.

4.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

4.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

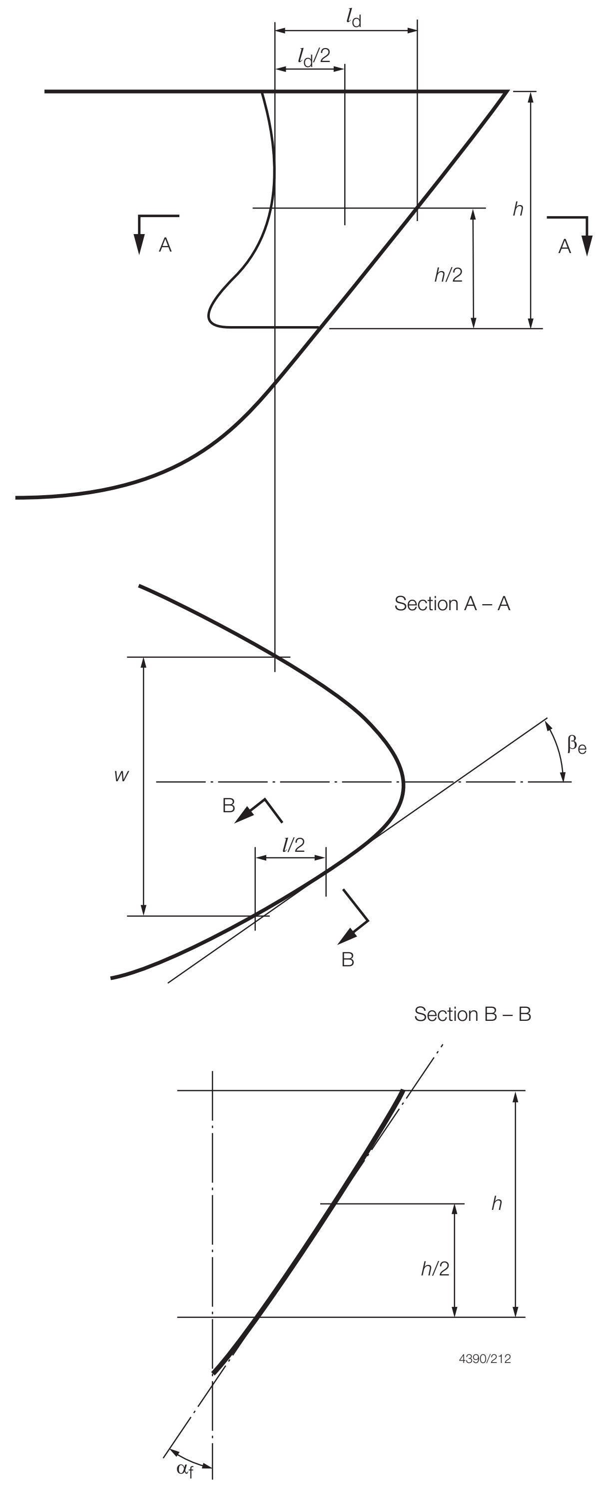


Fig. 5.4.1 Measurement of α_f and β_e

4.3.5 **Supporting device**. A device used to transmit external or internal loads from the door to a securing device and from the securing device to the craft's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the craft's structure.

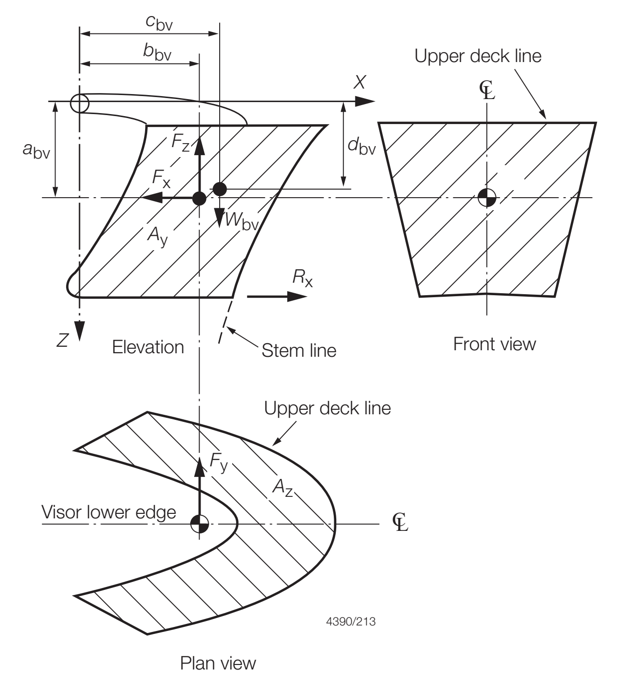


Fig. 5.4.2 Bow visor (upward hinging)

4.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

4.4 Strength criteria

4.4.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in 4.5. The shear, bending and equivalent stresses are not to exceed $43/k_a$ N/mm^2, $64/k_a$ N/mm^2 and $80/k_a$ N/mm^2 respectively.

4.4.2 The buckling strength of primary members is to be verified as being adequate, *see* Ch 7,4.

4.4.3 For metal to metal bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

4.4.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k_s$ N/mm^2.

4.5 Design loads

4.5.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is taken to be not less than the following:

$$P_e = 2{,}75\lambda_G C_H \left(0{,}22 + 0{,}15\tan\alpha_f\right)\left(0{,}4V_{max}\sin\beta_e + 0{,}6L_R^{0{,}5}\right)^2 \text{ kN/m}^2$$

where

C_H = $0{,}0125L_R$ for $L_R < 80$ m
= 1,0 for $L_R \geq 80$ m

L_R = Rule length of craft, in m as defined in Pt 3, Ch 1,6

V_{max} = maximum speed in knots as defined in Pt 1, Ch 2, 2.2.10.

λ_G = Service group factor for mono-hull craft, *see* Pt 1, Ch 2
= 0,5 for Group 1 and 2
= 0,6 for Group 3
= 0,8 for Group 4
= 1,0 for Group 5 and 6
For multi-hull craft, λ_G will be specially considered and may be reduced where the freeboard is significant

α_f = flare angle at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see* Fig. 5.4.1

β_e = entry angle at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see* Fig. 5.4.1.

4.5.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively.

where

P_e is the external pressure, defined in 4.5.1, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in Fig. 5.4.1.
A_x, A_y, A_z and h as defined in 4.3.1.

4.5.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

4.5.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10W_{bv} c_{bv} - F_z b_{bv} \text{ kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1
F_x and F_z are as defined in 4.5.2.

4.5.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

4.5.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of 0,45L_R and 10h_2, where h_2 is the distance, in m, from the load point to the top of the cargo space and L_R is as defined in Pt 3, Ch 1,6.2.1.

4.5.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

4.6 Scantlings of bow doors

4.6.1 The strength of bow doors is to be commensurate with that of the surrounding structure.

4.6.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

4.6.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

4.6.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between craft's frames and bow doors stiffeners.

4.6.5 The stiffener webs are to have a net sectional area A_s, not less than:

$$A_s = \frac{12{,}5Q_{bd}}{\sigma_a} \text{ cm}^2$$

where

A_s, Q_{bd} and σ_a are as defined in 4.3.1.

4.6.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

4.6.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

4.6.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in 4.5.1 and permissible stresses given in 4.4.2.

4.7 Scantlings of inner doors

4.7.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in and permissible stresses given in 4.4.1. In general, formulae for simple beam theory may be applied.

4.7.2 Where inner doors also serve as a vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

4.7.3 The distribution of the forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

4.8 Securing and supporting of bow doors

4.8.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

4.8.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in 4.8.8. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in 4.8.9 and 4.8.10 and the available space for adequate support in the hull structure.

4.8.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in 4.5.4 is to be not less than:

$$M_{ya} = 10W_{bv}\, c_{bv} + 0{,}1(a_{bv}{}^2 + b_{bv}{}^2)^{0{,}5}\ (F_x{}^2 + F_z{}^2)^{0{,}5}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} are as defined in 4.3.1
F_x and F_z are as defined in 4.5.2.

4.8.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in 4.4.1.

4.8.5 For **visor doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1 F_x and F_z.
Case 2 0,7F_y acting on each side separately together with 0,7F_x and 0,7F_z

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.6 For **side-opening doors** the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1 F_x , F_y and F_z acting on both doors.

Case 2 $0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where

F_x, F_y and F_z are to be determined as indicated in 4.5.2 and applied at the centroid of projected areas.

4.8.7 The support forces as determined according to 4.8.5 and 4.8.6 are to generally give rise to a zero moment about the transverse axis through the centroid of the area A_x. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

4.8.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

4.8.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in 4.4.1.

4.8.10 For **visor doors**, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in 4.4.1. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv}\, d_{bv} + 5A_x\, a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} are as defined in 4.3.1.

4.8.11 For **visor doors**, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force (F_z – $10W_{bv}$), in kN, within the permissible stresses given in 4.4.1.

4.8.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the craft structure, including welded connections, are to be the same strength.

4.8.13 For **side-opening doors**, thrust bearing has to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see* Fig. 5.4.3. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangements serving the same purpose are to be submitted for appraisal.

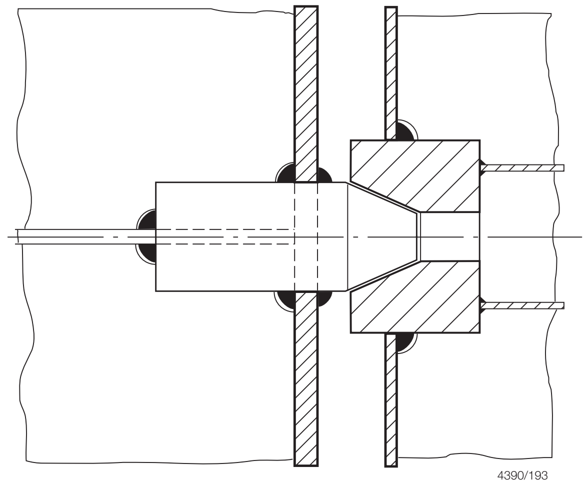


Fig. 5.4.3 Typical thrust bearing

4.9 Securing and locking arrangement

4.9.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

4.9.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the freeboard deck, of:

(a) the closing and opening of the doors; and

(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

4.9.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.9.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

4.9.5 The indicator system is to be designed on the fail-safe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.9.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the craft leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

4.9.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

4.9.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the engine control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

4.9.9 A drainage system is to be arranged in the area between bow door and ramp, as well as in the area between the ramp and inner door where fitted. The system is to be equipped with an audible alarm function to the navigation bridge for water level in these areas exceeding 0,5 m above the car deck level.

4.10 Operating and Maintenance Manual

4.10.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board and contain necessary information on:

(a) main particulars and design drawings,
(b) service conditions, e.g. service area restrictions, acceptable clearances for supports,
(c) maintenance and function testing,
(d) register of inspections and repairs.

This manual is to be submitted for approval.

4.10.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ *Section 5* Movable decks

5.1 Classification

5.1.1 Movable decks other than those described in 5.1.2 are not a classification item, although consideration must be given to associated supporting structure. Where movable decks are fitted, it is recommended that they be based on the requirements of this Section.

5.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Movable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.2 Arrangements and designs

5.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.2.2 Positive means of control are to be provided to secure decks in the lowered position.

5.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

5.3 Loading

5.3.1 Details of the deck loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN, *see* Section 3.

5.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

5.4 Scantling requirements

5.4.1 The scantlings and arrangements of removable decks are to be not less than those required by the Rules for the supporting structure in which the movable decks are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.5 Deflection

5.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

■ *Section 6* Helicopter landing areas

6.1 General

6.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the craft structure.

6.1.2 The structure is to be designed to accommodate the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

6.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

6.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

6.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

6.1.6 The requirements for fire protection, detection and extinction for yachts are to comply with Part 17. The requirements for other types of craft are outside the scope of classification and are therefore to comply with the requirements for the National Authority. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

6.2 Arrangements

6.2.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

6.2.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the Regulations.

6.2.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices, and in the case of independent platforms, safety nets, are to be provided.

6.2.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

6.2.5 Details of arrangements for securing the helicopter to the deck are to be submitted for approval.

6.3 Landing area plating

6.3.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha\, s}{1370\sqrt{k_a}}$$

α = thickness coefficient obtained from Fig. 5.3.1

β_p = tyre print coefficient used in Fig. 5.3.1

$= \log_{10}\left(\frac{3{,}5\, P_1\, k_a^2}{s^2} \times 10^7\right)$

where

s and k_a are as defined in 1.2.

The plating is to be designed for the emergency landing case taking:

$P_1 = 2{,}5\phi_1\, \phi_2\, \phi_3\, f\, \gamma\, P_w$ tonnes

where

ϕ_1, ϕ_2, ϕ_3 are to be determined from Table 5.3.1

f = 1,15 for landing decks over manned spaces, e.g., deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

P_h = the maximum all up weight of the helicopter, in tonnes

P_w = landing load on the tyre print, in tonnes:

For helicopters with a single main rotor, P_w is to be taken as P_h divided equally between the two main undercarriage wheels.

For helicopters with tandem main rotors, P_w is to be taken as P_h distributed between all main under-carriage wheels in proportion to the static loads they carry.

For helicopters fitted with landing gear consisting of skids, P_w is to be taken as P_h distributed in accordance with the actual load distribution given by the airframe manufacturer. If this is unknown, P_w is to be taken as $1/6P_h$ for each of the two forward contact points and $1/3P_h$ for each of the two aft contact points. The load may be assumed to act as a 300 mm x 10 mm line load at each end of each skid when applying Fig. 5.3.1.

γ = a location factor given in Table 5.6.1

For wheeled undercarriages, the tyre print dimensions specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 300 x 300 mm and this assumption is to be indicated on the submitted plan.

For skids and tyres with an asymmetric print, the print is to be considered oriented both parallel and perpendicular to the longest edge of the plate panel and the greatest corresponding value of α taken from Fig. 5.3.1.

6.4 Deck stiffening and supporting structure

6.4.1 The helicopter deck stiffening and supporting structure are to be designed for the load cases given in Table 5.6.2, with the helicopter being positioned so as to produce the most severe loading condition for each structural member under consideration.

6.4.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with Table 5.3.3.

6.4.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures be used to determine the scantling requirements, in association with the limiting permissible stress criteria given in Chapter 7. A copy of the calculations is to be submitted for consideration.

Table 5.6.1 Location factor, γ

Location	γ
On decks forming part of the hull girder: (a) within $0,4L_R$ amidships (b) at the F.P. or A.P.	0,71 Values for intermediate locations are to be 0,6 determined by interpolation
Elsewhere	0,6

Table 5.6.2 Design load cases for deck stiffening and supporting structure

Loadcase	Loads (tonnes)			
	Landing area		Supporting structure, *see* Note 1	
	UDL, in kN/m^2	Helicopter patch load, *see* Note 2	Self weight	Horizontal load, *see* Note 2
(1) Overall distributed loading	2	—	—	—
(2) Helicopter emergency landing	0,5	$2,5P_w f$	W_h	$0,5P_h$
(3) Normal Usage	0,5	$1,5P_w$	W_h	$0,5P_h + 0,5W_h$
Symbols				
P_h, P_w and f are as defined in 6.3.1 *UDL* = Uniformly distributed vertical load over entire landing area W_h = structural self-weight of helicopter platform, in tonnes				
NOTES 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads. 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.				

Section 7
Strengthening requirements for navigation in ice conditions

7.1 General

7.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

7.2 Shell plating

7.2.1 In way of the main ice belt zone, the thickness of the shell plating is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

7.2.2 Changes in plating thicknesses in the longitudinal direction are to take place gradually.

7.2.3 In general, all welded seams and butts in way of the main ice belt are to be dressed smooth.

7.3 Shell framing requirements

7.3.1 The section modulus of an ice framing stiffening member is to be determined by direct calculation. A copy of these direct calculations is to be submitted for consideration.

Section

Section 1
General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for mono-hull and multi-hull craft of aluminium construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave loading conditions.

1.2 Symbols and definitions

1.2.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section:

l = length of stiffening member, in metres
l_e = effective span length of stiffening member, in metres
p = design pressure as appropriately given in Part 3, in kN/m^2
s = spacing of stiffener, in mm
t_p = thickness of plating, in mm
B = moulded breadth of craft, in metres (to be taken as the breadth of a single hull for multi-hull craft)
L_R = Rule length of the craft, in metres
β = panel aspect ratio correction, *see* Ch 3,1.15
σ_a = 0,2 per cent proof stress of the alloy in the welded condition, in N/mm^2

$$\tau_a = \frac{\sigma_a}{\sqrt{3}}$$

1.2.2 The strength deck is to be taken as follows:
(a) Where there is a complete upper deck the strength deck is the upper deck.
(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell plating.

1.3.2 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

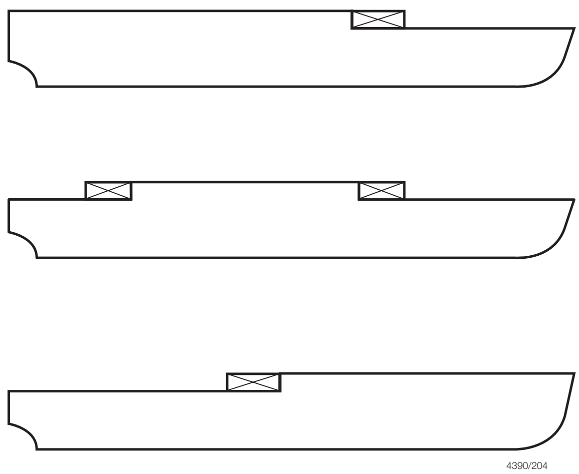


Fig. 6.1.1 Strength deck

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/Builder's calculations.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus (Z). The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

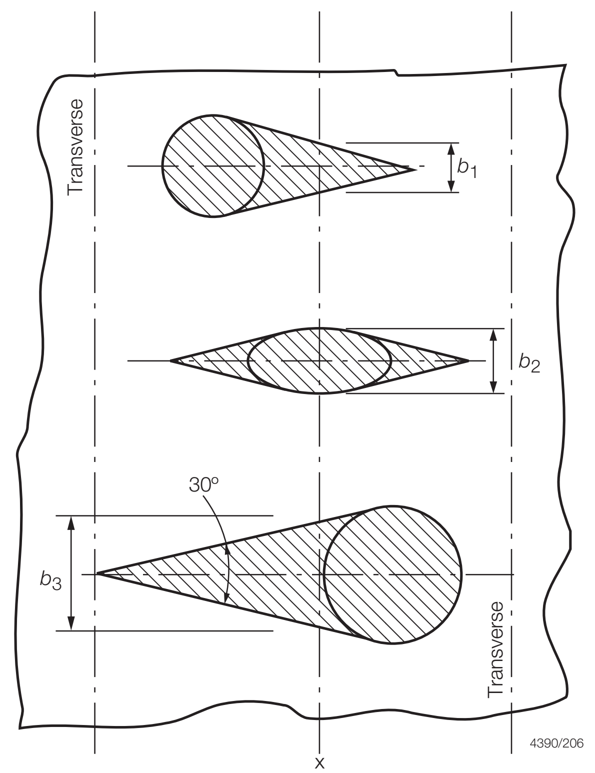
1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within 0,4L_R amidships. However, in special cases, based on consideration of type of craft, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the 0,4L_R part, bearing in mind the desire not to inhibit the craft's loading and operational flexibility.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1*B* m or a breadth exceeding 0,05*B* m are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.2 Deck openings smaller than stated in 1.4.1, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3) in one transverse section does not exceed 0,06 ($B_o - \Sigma\, b_o$):
where
B_o = breadth of craft, in metres, at section considered
$\Sigma\, b_o$ = sum of breadths, in metres, of deductible openings
Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.



Total equivalent breadth of small openings at xx = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the craft, and hence the required modulus, account is to be taken of the craft's actual form and weight distribution.

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular craft may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:
(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or tables of offsets may also be required.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, to include the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2* Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 45 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 45 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 75 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be of deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} \geq 3{,}0$ is to satisfy both the following criteria:

$\sigma_k + \sigma_l + \sigma_t < 1{,}2\sigma_P$

$\sigma_d < \sigma_P$

where

σ_P = maximum permissible hull vertical bending stress, in N/mm^2
= $f_{\sigma gH}\, \sigma_a$

$f_{\sigma gH}$ = limiting hull bending stress coefficient taken from Table 7.3.2 in Chapter 7

L_{WL} is as defined in Pt 3, Ch 1,6.2.5

σ_k, σ_l, σ_t and σ_d are given in Table 6.2.1

σ_a is as defined in 1.2.1.

Table 6.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships	$\sigma_d = \dfrac{M_R}{1000 Z_d}$
Hull girder bending stress at keel amidships	$\sigma_k = \dfrac{M_R}{1000 Z_k}$
Actual stress in bottom longitudinals amidships due to design pressure load	$\sigma_l = \dfrac{p_s\, s\, l_e^2}{12 Z_l}$
Actual stress in bottom plating amidships due to design pressure load	$\sigma_t = 0{,}34 p_t \left(\dfrac{\beta s}{t_p}\right)^2 \times 10^{-3}$
Symbols and definitions	
M_R = design longitudinal midship bending moment, in kNm given in Pt 5, Ch 5,5 p_s = additional effective pressure loading, in kN/m^2, on bottom longitudinals from global dynamic load model, given in Pt 5, Ch 5,2.6.3 p_t = additional effective pressure loading, in kN/m^2, on bottom plating from global dynamic load model, given in Pt 5, Ch 5,2.6.4 Z_d = actual section modulus at deck, in m^3 Z_k = actual section modulus at keel, in m^3 Z_l = maximum section modulus of bottom longitudinal stiffener, associated with plating, amidships, in cm^3 s, l_e, β and t_p are as defined in 1.2.	

2.2.3 The longitudinal strength of craft with $\dfrac{V}{\sqrt{L_{WL}}} < 3{,}0$ is to satisfy both the following criteria:

$\sigma_k < \sigma_P$

$\sigma_d < \sigma_P$

where

σ_P is as defined in 2.2.2

σ_k and σ_d, are given in Table 6.2.1

L_{WL} is as defined in Pt 3, Ch 1,6.2.5.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along its length is to satisfy the following criterion:

$$\frac{Q_R}{A_\tau} 10^{-3} \leq \tau_p$$

where

Q_R = design hull shear force at any section along the hull length, L_R, in kN determined from Pt 5, Ch 5,5

A_τ = shear area of transverse section, in m^2, is to be taken as the effective net sectional area of the shell plating and longitudinal bulkheads after deductions for openings. For longitudinal strength members which are inclined to the vertical, the area of the member to be included in the calculation is to be based on the area projected onto the vertical plane, *see* Fig. 6.2.1

τ_p = maximum permissible mean shear stress, in N/mm^2
= $f_{\sigma g} \tau_a$

$f_{\sigma g}$ = limiting hull shear stress coefficient taken from Table 7.3.2 in Chapter 7

τ_a is as defined in 1.2.1.

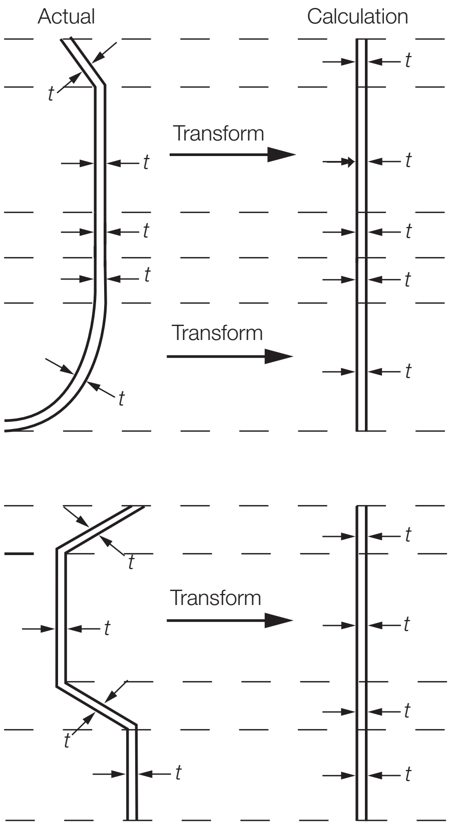


Fig. 6.2.1 Effective shear area

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form of Rule length, L_R, less than 75 m and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with large deck openings, unusual form or proportions. Calculations may in general be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

2.5 Superstructures global strength

2.5.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4L amidship and where:

$$l_d > b_d + 3h_d$$

where

l_d = length of first tier, in metres
b_d = breadth of first tier, in metres
h_d = 'tween deck height of first tier, in metres.

2.5.2 For superstructures with one or two tiers extending outboard to the craft's side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_s = 7\left[(\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5{,}8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma\right] f(\lambda, N) \times 10^{-7}$$

where

$f(\lambda, N = 1) = 1$

$f(\lambda, N = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7 l_1$
= 2 if $l_2 \geq 0{,}7 l_1$

$\lambda = \dfrac{l_w}{L_R}$ or 1, whichever is less

$\varepsilon = \dfrac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \dfrac{l_w}{h_1}$ or 25, whichever is less

$l_w = l_1$ for $N = 1$
$= \dfrac{(2l_1 + l_2)}{3}$ for $N = 2$

L_R = is as defined in 1.2.1, in metres
l_1, b_1, h_1 = is as defined in 2.5.1, in metres
l_2 = length of second tier, in metres.

2.5.3 The hull girder compressive bending stress σ_L, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_L = \eta_s \frac{M_R}{1000 Z_{100}} \text{ N/mm}^2$$

where

M_R = hull girder bending moment at midships due to sagging as determined in Pt 5, Ch 5,5, in kNm
Z_{100} = section modulus at uppermost effective tier of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^3
η_s = as defined in 2.5.2.

2.5.4 The compressive stress, σ_L, in the uppermost effective tier at side is to be checked against buckling in accordance with Ch 7,4.

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_s = \left(1 + \frac{Z_0\, h}{I_{100}}\right)^{-1}$$

where
η_s = as defined in 2.5.2
Z_0 = section modulus of hull only at hull upper deck, in m^3
I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4
h = height from hull upper deck to uppermost effective tier, in metres.

■ *Section 3* Additional hull girder strength requirements for multi-hull craft

3.1 General

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

3.1.3 For craft of ordinary hull form length with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion, dependent upon the proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 60 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are in general to be complied with, using the appropriate design bending moment and effective pressure loadings applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with so far as they are applicable.

3.4 Torsional strength

3.4.1 Where a craft is of unusual form or novel construction, or at the discretion of LR, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5,5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Design loads to be applied for scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

3.5.2 The primary stiffening members of the cross-deck structure are to provide sufficient strength to satisfy the stress criteria given in Table 6.3.1.

3.5.3 The component nominal stresses may be determined in accordance with Table 6.3.2 in the case where the cross-deck is formed by transverse primary stiffeners or bulkheads and the following assumptions are taken:
(a) The cross-deck is symmetrical forward and aft of a transverse axis at its half length.
(b) Primary stiffeners having the same scantlings and spacing.

3.5.4 Other cross-deck designs subjected to global transverse loads will require a two-dimensional grillage analysis to be performed to demonstrate compliance with 3.5.2.

3.5.5 Section properties are to be calculated using an effective breadth of plating to be determined in accordance with Ch 3,1.11.

Table 6.3.1 Primary member stress criteria

Stress type	Component stresses	Allowable stress level (N/mm^2)
Total direct stress, σ_P	$\sigma_P = \sigma_{MB} + \sigma_{MT} + \sigma_d$	$f_{\sigma gV}\,\sigma_a$
Total shear stress, τ_P	$\tau_P = \tau_T + \tau_{MBT} + \tau_{MT}$	$f_{\tau gV}\,\tau_a$
Equivalent stress, σ_{eq}	$\sigma_{eq} = \sqrt{\sigma^2 + 3\tau^2}$	$1{,}2\, f_{\sigma eg}\,\sigma_a$
Symbols and definitions		
σ_{MB}, σ_{MT}, τ_T, τ_{MBT} and τ_{MT} are component stresses, in N/mm^2, to be taken from Table 6.3.2. $f_{\sigma gV}$, $f_{\tau gV}$ and $f_{\sigma eg}$ are limiting stress coefficients for cross-deck structures to be taken from Table 7.3.2 in Chapter 7. σ_a and τ_a are defined in 1.2.		

Table 6.3.2 Cross-deck component stresses for designs complying with 3.5.3

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck amidships, *see* Table 6.2.1	$\sigma_d = f_{MR} \dfrac{M_R}{1000 Z_d}$
Stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5	$\sigma_{MB} = f_{MB} \dfrac{M_B}{nZ} 10^3$
Stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\sigma_{MT} = f_{MT} \dfrac{3x_H M_T}{n(n+1)\, s_p Z} 10^3$
Shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5	$\tau_T = f_{MB} \dfrac{5Q_T}{n A_w}$
Bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MBT} = f_{MT} \dfrac{60 M_T}{n(n+1)\, s_p A_w}$
Shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5	$\tau_{MT} = f_{MT} \dfrac{46\kappa\, x_H^2 M_T}{n(n^2+1)\, s_p^2 I_y} 10^3$
Symbols and definitions	

Q_T = vertical shear force, in kN, as determined from, Pt 5, Ch 5,5
M_B = transverse bending moment in kNm, as determined from Pt 5, Ch 5,5
M_T = torsional moment in kNm, as determined from Pt 5, Ch 5,5
n = total number of transverse primary stiffeners or bulkheads
A_w = stiffener web area, cm^2
Z = primary stiffeners section modulus, in cm^3
s_p = stiffener spacing, in metres
I_y = moment of inertia of stiffener, cm^4
x_H = transverse distance between the centre of the two hulls, in metres
κ = t_f, for symmetrical I-section, in mm
= $b_b\, h/(b_b + h)$, for constant thickness box sections, in mm
σ_{MB} = stress induced by the transverse bending moment M_B, as defined in Pt 5, Ch 5,5, in N/mm^2
σ_{MT} = stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_T = shear stress induced by the vertical shear force Q_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MBT} = bending shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
τ_{MT} = shear stress induced by the torsional moment M_T, as defined in Pt 5, Ch 5,5, in N/mm^2
t_f = face plate thickness, in mm
b_b = breadth of box section, in mm
h_b = height of box section, in mm

f_{MR}, f_{MB} and f_{MT} are load combination factors reflecting the portions of each component global design load, M_R, Q_T, M_B and M_T, corresponding to the most severe load combinations, The most severe load combinations are the combinations of loads resulting in the maximum bending, shear and effective stress, respectively. The assessment of these load combinations need to take due consideration for the component load magnitude variation with wave heading and also the phasing in time between them. Generally, f_{MR}, f_{MB}, and f_{MT} are to be taken as indicated in Table 6.3.3.

Table 6.3.3 Load combination factors

Heading	Factors		
	f_{MB}	f_{MR}	f_{MT}
Head sea	0,1	1,0	0,1
Beam sea	1,0	0,1	0,2
Quartering sea	0,1	0,4	1,0

3.5.6 Where primary stiffening members support areas of plating of the extruded plank type, or the floating frame system is used, the effect of the plating attached to the secondary stiffening members is to be ignored when determining the global section modulus requirements.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of aluminium construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in the formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculation methods are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined in the appropriate Sections.

1.4 Direct calculations

1.4.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.4.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

■ *Section 2* Deflection control

2.1 General

2.1.1 The limiting deflection requirements for plate panels and stiffening members are given in terms of limiting deflection coefficient, f_δ, *see* Table 7.2.1. The coefficient equates to a span/deflection ratio in consistent units.

Table 7.2.1 Limiting deflection ratio

Item		Deflection ratio, f_δ
Bottom structure:	• secondary stiffening	475
	• primary girders and web frames	625
Side structure:	• secondary stiffening	475
	• primary girders and web frames	625
Main/strength deck structures:	• secondary stiffening	625
	• primary girders and web frames	775
	• hatch covers	775
Superstructures/deckhouses stiffeners:		
(a) Generally:	• secondary	400
	• primary	475
(b) Coachroof:	• secondary	475
	• primary	625
(c) House top:	• secondary	400
	• primary	400
Lower/inner decks and house top, subject to personnel loading:	• secondary members	475
	• primary members	625
Deep tank stiffeners:	• secondary members	625
	• primary members	775
Watertight bulkhead stiffeners:	• secondary members	400
	• primary members	475
Multi-hull cross-deck stiffeners:	• secondary members	475
	• primary members	625
Vehicle deck stiffeners:	• secondary members	625
	• primary members	775
Helicopter/flight deck stiffeners:	• secondary members	625
	• primary members	775
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.		

Section 3
Stress control

3.1 General

3.1.1 The nominal limiting stress requirements for plating and primary and secondary stiffening members subject to local loading conditions are given in terms of limiting stress coefficients, *see* Table 7.3.1. The coefficients are expressed as a proportion of the 0,2 per cent proof stress of the material.

3.1.2 The limiting stress coefficients for structural elements subject to global loading conditions are given in Table 7.3.2.

3.1.3 In the determination of the magnitude of the equivalent stress, σ_{eq}, it is assumed that the stresses are combined using the following formula:

$$\sigma_{eq} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_x \sigma_y + 3\tau^2}$$

where

σ_x = direct stress in the x direction
σ_y = direct stress in the y direction
τ = shear stress in the xy plane.

Table 7.3.1 Limiting stress coefficients for local loading (*see continuation*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Shell envelope:				
(a) Bottom shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Side shell plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(c) Keel		0,75	—	—
Bottom structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
(c) Engine girders		0,55	0,55	0,75
Side structure:				
(a) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(b) Primary girders and web frames		0,65	0,65	0,75
Bow doors:				
(a) Plating		0,65	—	—
(b) Secondary stiffening		0,51	0,433	—
(c) Primary stiffening		0,51	0,34	0,64
Main/strength deck plating and stiffeners:				
(a) Plating		0,75	—	—
(b) Secondary stiffening		0,65	0,65	—
(c) Primary girders and web frame		0,65	0,65	0,75
(d) Hatch covers		0,55	0,55	0,64

Table 7.3.1 Limiting stress coefficients for local loading (*conclusion*)

Item		Limiting stress coefficient		
		Bending f_σ	Shear f_τ	Equivalent f_e
Superstructures/deckhouses:				
(a) Deckhouse front, 1st tier:	• plating	0,65	—	—
	• stiffening	0,60	0,60	—
(b) Deckhouse front, upper tiers:	• plating	0,75	—	—
	• stiffening	0,65	0,65	—
(c) Deckhouse aft and sides:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(d) Coachroof:	• plating	0,65	—	—
	• stiffening	0,65	0,65	—
(e) House top:	• plating	0,75	—	—
	• stiffening	0,75	0,75	—
(f) Lower/inner decks and house top, subject to personnel loading:	• plating	0,75	—	—
	• stiffening	0,60	0,60	—
Bulkheads:				
(a) Watertight bulkhead:	• plating	1,0	—	—
	• secondary stiffening	0,95	0,95	—
	• primary stiffening	0,90	0,90	1,0
(b) Watertight bulkhead doors		0,825	0,825	0,825
(c) Structure supporting watertight doors		0,80	0,80	—
(d) Minor bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,65	0,65	0,75
(e) Deep tank bulkheads:	• plating	0,65	—	—
	• secondary stiffening	0,65	0,65	—
	• primary stiffening	0,75	0,75	—
Multi-hull cross-deck structure:				
(a) Plating:	• slamming zone	0,85	—	—
	• elsewhere	0,75	—	—
(b) Secondary stiffening:	• slamming zone	0,75	0,75	—
	• elsewhere	0,65	0,65	—
(c) Primary stiffening		0,65	0,65	0,75
Vehicle deck:				
(a) Plating		0,60	—	—
(b) Secondary stiffening		0,425	0,425	—
(c) Primary stiffening		0,525	0,525	0,75
Helicopter/flight decks:				
(a) Normal usage:	• plating	0,65	—	—
	• secondary stiffening	0,75	0,75	—
	• primary stiffening	0,625	0,625	0,60
(b) Emergency landing:	• plating	0,75	—	—
	• secondary stiffening	1,0	1,0	—
	• primary stiffening	0,825	0,825	0,9
(c) Crane pedestal/foundation structural elements		0,7	0,7	0,75

Table 7.3.2 Limiting stress coefficients for global loading

Operational mode of craft	Limiting stress coefficient					
	Hull girder			Cross-deck		
	Bending $f_{\sigma gH}$	Shear $f_{\tau gH}$	Equivalent $f_{\sigma eg}$	Bending $f_{\sigma gV}$	Shear $f_{\tau gV}$	Equivalent $f_{\sigma eg}$
$\Gamma \geq 3,0$ $\Delta \leq 0,04\ (L_R\, B)^{1,5}$	0,80	0,80	0,825	0,80	0,80	0,825
$\Gamma < 3,0$ and $\Delta > 0,4\ (L_R\, B)^{1,5}$	0,72	0,72	0,75	0,72	0,72	0,75

Symbols

$f_{\sigma gH}$ = limiting hull bending stress coefficient
$f_{\tau gH}$ = limiting hull shear stress coefficient
$f_{\sigma gV}$ = limiting cross-deck bending stress coefficient
$f_{\tau gV}$ = limiting cross-deck shear stress coefficient
$f_{\sigma eg}$ = limiting equivalent stress coefficient
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16
Δ is the displacement as defined in Pt 5, Ch 2,2
L_R and B are as defined in Pt 3, Ch 1,6.2

Section 4
Buckling control

4.1 General

4.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

4.1.2 The requirements for buckling control of plate panels are contained in 4.3 to 4.6. The requirements for secondary stiffening members are contained in 4.7 to 4.8. The requirements for primary members are contained in 4.9 and 4.10.

4.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as follows:

(a) Global hull girder bending and shear stresses given in Chapter 6, but not including stresses σ_l and σ_t as defined in Table 6.2.1 in Chapter 6.
(b) Stresses from local compressive loads.

4.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or Owner's extra is not included in scantlings used to assess the buckling performance.

4.2 Symbols

4.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

a = panel length, i.e. parallel to direction of com-pressive stress being considered, in mm
b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm
b_{eb} = lesser of $1,9 t_p \sqrt{\dfrac{E}{\sigma_a}}$ or $0,8b$ mm
l = length of longer edge of plate panel, in metres
s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)
t_p = thickness of plating, in mm
A_R = panel aspect ratio
$= \dfrac{a}{b}$
A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}
E = modulus of elasticity of material in N/mm^2
S = spacing of primary member, in metres (measured in direction of compression)
S_p = span of primary members, in metres
σ_a = 0,2 per cent proof stress of the material, in N/mm^2
σ_e = elastic compressive buckling stress, in N/mm^2
σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2
τ_a = specified minimum yield shear stress of the material, in N/mm^2
$= \dfrac{\sigma_a}{\sqrt{3}}$ N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
τ_c = critical shear buckling stress, in N/mm^2.

4.3 Plate panel buckling requirements

4.3.1 This Section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:
(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

4.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in Table 7.4.2 for the above load fields are complied with.

4.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for Table 7.4.2 are to be derived in accordance with 4.4.

4.3.4 The buckling factors of safety λ_σ and λ_τ required by Table 7.4.2 are given in Table 7.4.4 for the structural member concerned.

4.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, Table 7.4.2(a), and shear loads, Table 7.4.2(b) are to be complied with.

4.3.6 In addition to 4.3.5, structural members which are subjected to local compressive loads and/or shear loads are to be verified using the plate panel buckling requirements in Table 7.4.2(c) to (e).

4.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of 4.5 must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation.

4.3.8 In general the plate panel buckling requirements for more complex load fields, *see* 4.3.1(c), (d), (e), are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from 4.5.4, instead of the elastic buckling stress, σ_e, derived in 4.3.5. In addition, the requirements of 4.5 are to be met for the supporting secondary stiffeners and primary members.

4.4 Derivation of the buckling stress for plate panels

4.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with Table 7.4.1(a).

4.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with Table 7.4.1(b).

4.4.3 For welded plate panels the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress is to be taken as the minimum of:

$\sigma_{cr} = \sigma_e - \sigma_r$

σ_c derived using 4.4.1

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\,\sigma_a}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

b, t_p and σ_a are defined in 4.2.1.

4.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

4.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

4.5 Additional requirements for plate panels which buckle elastically

4.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:
(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e,
$\sigma_d > \sigma_e$
(b) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_a}{2}$$

4.5.2 Elastic buckling of local plating between stiffeners, including girders or floors, etc., may be allowed if all of the following conditions are satisfied:
(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c\,(i)}} \leq \frac{1}{\lambda_\sigma}$$

(b) Maximum predicted loadings are used in the calculations.
(c) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in 4.5.5

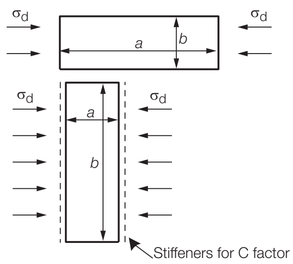
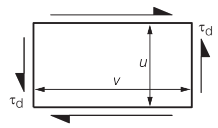
$\sigma_{c\,(i)}$ is given by Table 7.4.3

where

i = a, t, w or f depending on the mode of buckling

λ_σ is the buckling factor of safety = 1,25.

Table 7.4.1 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2, *see* Note	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3{,}62\varphi E \left(\frac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0{,}9C\varphi \left(\frac{b}{a} + \frac{a}{b}\right)^2 E \left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3{,}62\left(1{,}335 + \left(\frac{u}{v}\right)^2\right) E \left(\frac{t_p}{u}\right)^2$ NOTE *u* is to be the minimum dimension	

NOTE
The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_a}{2}$$

$$= \sigma_a\left(1 - \frac{\sigma_a}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_a}{2}$$

σ_c is defined in 4.2.1
σ_a is defined in 4.2.1

$$\tau_c = \tau_e \text{ when } \tau_e < \frac{\tau_a}{2}$$

$$= \tau_a\left(1 - \frac{\tau_a}{4\tau_e}\right) \text{ when } \tau_e \geq \frac{\tau_a}{2}$$

τ_c is defined in 4.2.1
τ_a is defined in 4.2.1

Symbols

A_R = panel aspect ratio, *see* 4.2.1
σ_e = elastic compressive buckling stress, in N/mm^2
τ_e = elastic shear buckling stress, in N/mm^2
a and *b* are the panel dimensions in mm, *see* figures above
t_p = thickness of plating, in mm
φ = stress distribution factor for linearly varying compressive stress across plate width
= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$
= 1 for constant stress

$\mu = \dfrac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2
C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress
= 1,3 when plating stiffened by floors or deep girders
= 1,21 when stiffeners are built up profiles or rolled angles
= 1,10 when stiffeners are bulb flats
= 1,05 when stiffeners are flat bars
σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}

4.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\sigma_u}{\sigma_a} \text{ mm}$$

where

σ_u = ultimate buckling strength of plating as given in 4.5.4
b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered
b is given in 4.2.1.

4.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_a\left(\frac{1{,}9}{\Omega} - \frac{0{,}8}{\Omega^2}\right) \text{ N/mm}^2$$

(b) longest edge loaded, i.e. $A_R < 1$:

$$\sigma_u = \frac{1{,}77\sigma_a A_R^{0{,}78}}{\Omega} \text{ N/mm}^2$$

where

$$\Omega = \frac{s}{t_p}\sqrt{\frac{\sigma_a}{E}}$$

A_R and s are defined in 4.2.1.
t_p, E and σ_a are defined in 4.2.1.

4.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100} \text{ cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}\, t}{100} \text{ cm}^2$$

where

b and b_{eu} are given in 4.5.3
t is the plating thickness, in mm
A_s is the stiffener area in cm^2.

4.6 Shear buckling of stiffened panels

4.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \le \frac{1}{\lambda_\tau}$$

where

τ_c is derived from 4.6.3
τ_d is the design shear stress
λ_τ is given in Table 7.4.4.

4.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E \left(\frac{t}{s}\right)^2 \quad \text{for } A_R \ge 1$$

where

$$K_s = 4{,}5 \left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2 - 1}{N^2}\right)\left(\frac{\omega}{1 + \omega}\right) \right)^r$$

N = number of subpanels

$$= \frac{1000 S_p}{s}$$

$$\omega = 10 I_{se}$$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width *s*/2

$$r = 1 - 0{,}75 \left(\frac{s}{1000l}\right)$$

s, *l*, *E* and S_p are as defined in 4.2.1, *see also* Fig. 7.4.1.

4.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note in Table 7.4.1.

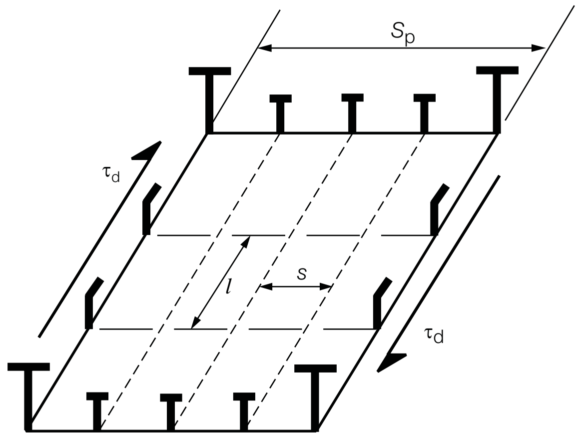


Fig. 7.4.1 Shear buckling of stiffened panels

4.7 Secondary stiffening in direction of compression

4.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \le \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \le \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \le \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \le \frac{1}{\lambda_\sigma}$$

where

$\sigma_{c(a)}$, $\sigma_{c(t)}$, $\sigma_{c(w)}$ and $\sigma_{c(f)}$ are the critical buckling stresses of the stiffener for each mode of failure, *see* 4.7.2
σ_d is the design compressive stress, *see also* 4.5 and 4.1.3
λ_σ is the buckling factor of safety given in Table 7.4.4. The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 1 in Table 7.4.4.

4.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with Table 7.4.3.

4.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in 4.4.1.

4.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$$\sigma_{c(w)} > \sigma_{c(t)}$$
$$\sigma_{c(f)} > \sigma_{c(t)}$$

4.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence

$$\sigma_{c(a)} > \sigma_{c(t)}$$

4.8 Secondary stiffening perpendicular to direction of compression

4.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see* Fig. 7.4.2, e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this Section are to be applied.

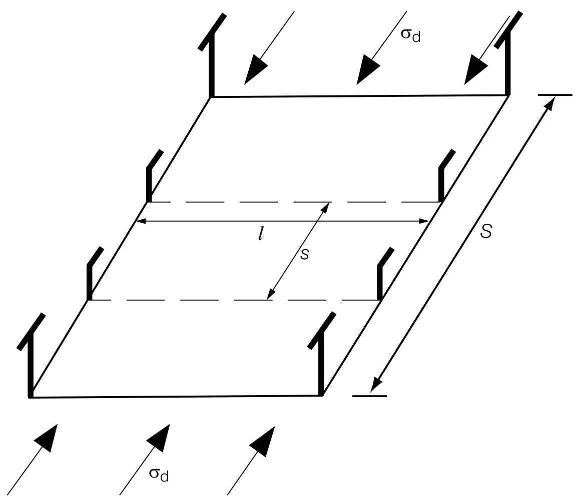


Fig. 7.4.2
Secondary stiffening perpendicular to direction of compression

4.8.2 The minimum area moment of inertia of each stiffener including attached plating of width, *s*, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\, s\,(4N_L^2 - 1)((N_L^2 - 1)^2 - 2\,(N_L^2 + 1)\,\kappa + \kappa^2)}{2\,(5N_L^2 + 1 - \kappa)\,\Pi^4\,E}\ \text{mm}^4$$

where

$D = \dfrac{E\, t_p^3}{12\,(1 - \upsilon^2)}$

$\kappa = A_R^2\, \Pi^2$

A_R = plate panel aspect ratio

$= \dfrac{s}{1000l}$

$\Pi = \dfrac{S}{l}$

N_L = number of plate panels

$N_L - 1$ = number of stiffeners

υ = 0,3

s, *l* and *S* are defined in 4.2.1 and shown in Fig.7.4.2

t_p, *E* are defined in 4.2.1.

4.9 Buckling of primary members

4.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in 4.7 are to be satisfied.

4.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_g = \frac{0{,}35 S_p^4\, I_s}{l^3\, s} \times 10^3 \ \text{cm}^4$$

S_p and *s* are as defined in 4.2.1, *see also* Fig.7.4.1

I_g = sectional moment of inertia including attached plating

I_s = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the overall elastic column buckling mode requirement specified in Table 7.4.3

$$= \frac{\sigma_{ep}\, A_{te}\, l_e^2}{0{,}001E}$$

where

$\sigma_{ep} = 1{,}2\sigma_d$ N/mm^2 for $\sigma_{e(a)} < \dfrac{\sigma_a}{2}$

$= \dfrac{\sigma_a^2}{4\,(\sigma_a - 1{,}2\sigma_d)}$ for $\sigma_{e(a)} \geq \dfrac{\sigma_a}{2}$

σ_d is design stress, in N/mm^2

σ_a and A_{te} are as defined in 4.2.1.

$\sigma_{e(a)}$ is the elastic column buckling stress, *see* 4.7.2

E is defined in 4.2.1

l_e is defined in Table 7.4.3.

4.10 Shear buckling of girder webs

4.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in Table 7.4.2, item (b).

4.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in Table 7.4.1.

$$\tau_e = 3{,}62 \left(1{,}335 + \left(\frac{d_w}{1000 l_p}\right)^2\right) E \left(\frac{t_p}{d_w}\right)^2 \ \text{N/mm}^2$$

where

d_w = web height, in mm

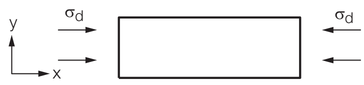
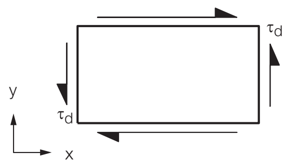
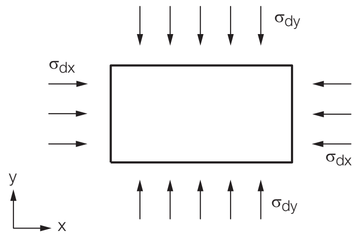
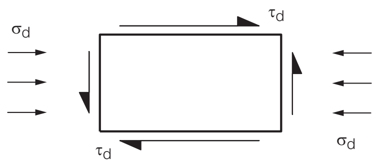
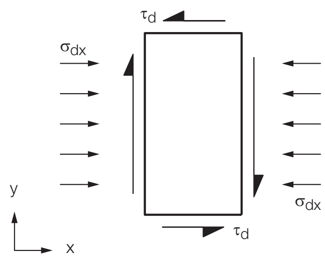
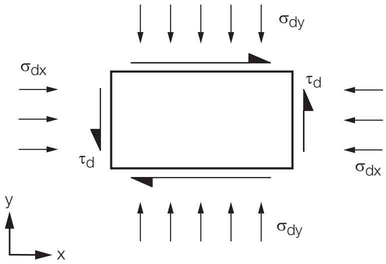
l_p = unsupported length of web, in metres

t_p and *E* are defined in 4.2.1.

4.11 Pillars and pillar bulkheads

4.11.1 Pillars and pillar bulkheads are to comply with the requirements of Ch 3,10.

Table 7.4.2 Plate panel buckling requirements

	Stress field	Buckling Interaction formula	
(a)	uni-axial compressive loads	$\dfrac{\sigma_d}{\sigma_c} \le \dfrac{1}{\lambda_\sigma}$	
(b)	shear loads	$\dfrac{\tau_d}{\tau_c} \le \dfrac{1}{\lambda_\tau}$	
(c)	bi-axial compressive loads	for A_R = 1,0 $\dfrac{\sigma_{dx}}{\sigma_{cx}} + \dfrac{\sigma_{dy}}{\sigma_{cy}} \le 1{,}0$ for other aspect ratios, i.e. $A_R \ne 1{,}0$ $\dfrac{\sigma_{dx}}{\sigma_{cx}} + \dfrac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from Fig. 7.4.3	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\dfrac{\sigma_d}{\sigma_c}\right) + \left(\dfrac{\tau_d}{\tau_c}\right)^2 \le 1$ for $A_R \le 1$ $\left(\dfrac{1 + 0{,}6A_R}{1{,}6}\right)\left(\dfrac{\sigma_d}{\sigma_c}\right) + \left(\dfrac{\tau_d}{\tau_c}\right)^2 \le 1$	 
(e)	bi-axial compressive loads plus shear loads	$\dfrac{0{,}625\left(1 + \dfrac{0{,}6}{A_R}\right)\left(\dfrac{\sigma_{dy}}{\sigma_{cy}}\right)}{1 - 0{,}625\left(\dfrac{\sigma_{dx}}{\sigma_{cx}}\right)} + \dfrac{\left(\dfrac{\tau_d}{\tau_c}\right)^2}{1 - \left(\dfrac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols

- σ_d = design compressive stress, *see* 4.1.3
- σ_c = critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see* 4.3.5
- σ_{dx} = design compressive stress in x direction
- σ_{dy} = design compressive stress in the y direction
- σ_{cx} = critical compressive buckling stress in x direction, *see* 4.3.5
- σ_{cy} = critical compressive buckling stress in y direction, *see* 4.3.5
- λ_σ = buckling factor of safety for compressive stresses, *see* 4.3.4
- λ_τ = buckling factor of safety for shear stresses, *see* 4.3.4
- τ_d = design shear stress, in N/mm^2
- τ_c = critical shear buckling stress, in N/mm^2, acting independently, *see* 4.3.5
- A_R = *see* 4.2.1

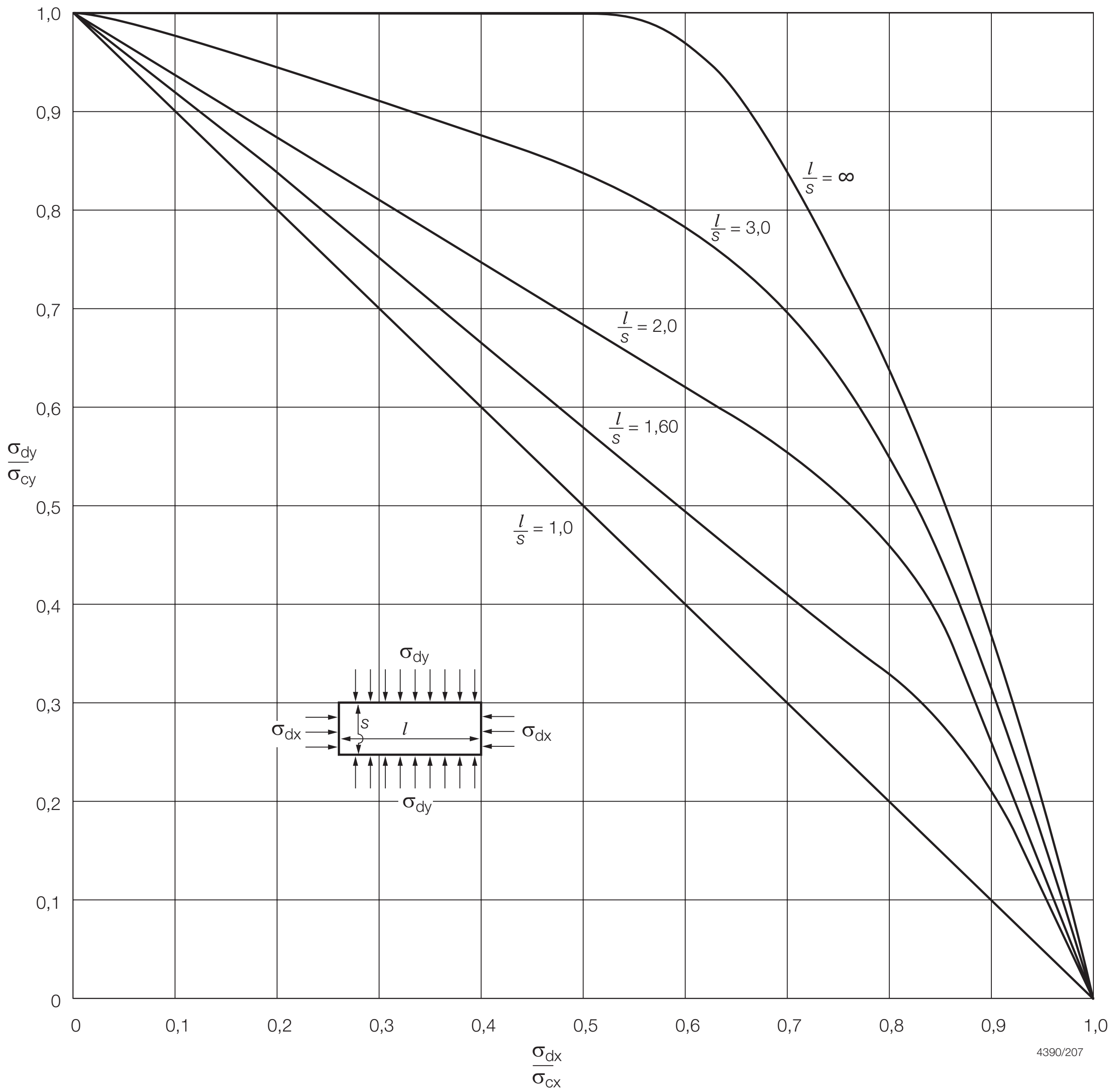


Fig. 7.4.3
Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 7.4.2(c)

Table 7.4.3 Buckling stress of secondary stiffeners (*see continuation*)

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f\, 0{,}001\, E \quad I_a$	$\sigma_{c(a)}$
(b) Torsional buckling	$\sigma_{e(t)} = \dfrac{0{,}001E\, I_w}{I_p\, l_e^2}\left(m^2 + \dfrac{K}{m^2}\right) + 0{,}385E\,\dfrac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3{,}8\, E\left(\dfrac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 0{,}39\, E\left(\dfrac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

$$\sigma_c = \sigma_e \text{ when } \sigma_e < \frac{\sigma_a}{2}$$

$$= \sigma_a\left(1 - \frac{\sigma_a}{4\sigma_e}\right) \text{ when } \sigma_e \geq \frac{\sigma_a}{2}$$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see* Fig. 7.4.4
t_w = web thickness, in mm
b_f = flange width, in mm (including web thickness)
t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see* Fig. 7.4.4
l_e = effective span length of stiffener, in metres
C_f = end constraint factor
= 1 where both ends are pinned
= 2 where one end pinned and the other end fixed
= 4 where both ends are fixed
E = Youngs Modulus of elasticity of the material, in N/mm^2
I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}, *see* Note
t_p and σ_a are given in 4.2.1
A_{te} and b_{eb} are given in 4.2.1

NOTE
For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

Table 7.4.3 Buckling stress of secondary stiffeners (*conclusion*)

I_t = St.Venant's moment of inertia, in cm^4, of longitudinal (without attached plating)

$= \dfrac{d_w t_w^3}{3} 10^{-4}$ for flat bars

$= \dfrac{1}{3}\left[d_w t_w^3 + b_f t_f^3 \left(1 - \dfrac{0{,}63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \dfrac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

$= \left(\dfrac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectorial moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \dfrac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

$= \dfrac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

$= \dfrac{b_f^3 d_w^2}{12 (b_f + d_w)^2} (t_f (b_f^2 + 2b_f d_w + 4d_w^2) + 3t_w b_f d_w) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$= \dfrac{k_p E t_p^3}{3b\left(1 + \dfrac{1{,}33 k_p d_w t_p^3}{b t_w^3}\right)}$

k_p = $1 - \eta_p$, and is not to be taken as less than zero. For built-up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

$\eta_p = \dfrac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from Table 7.4.1

m is determined as follows; e.g. $m = 2$ for $K = 25$

K	0 to 4	4 to 36	36 to 144	144 to 400	400 to 900	900 to 1764	$(m-1)^2 m^2$ to $m^2 (m+1)^2$
m	1	2	3	4	5	6	m

$K = \dfrac{1{,}03 C S^4}{E I_w} 10^4$

σ_d is the design stress, in N/mm^2
all other symbols are as defined in 4.2.1

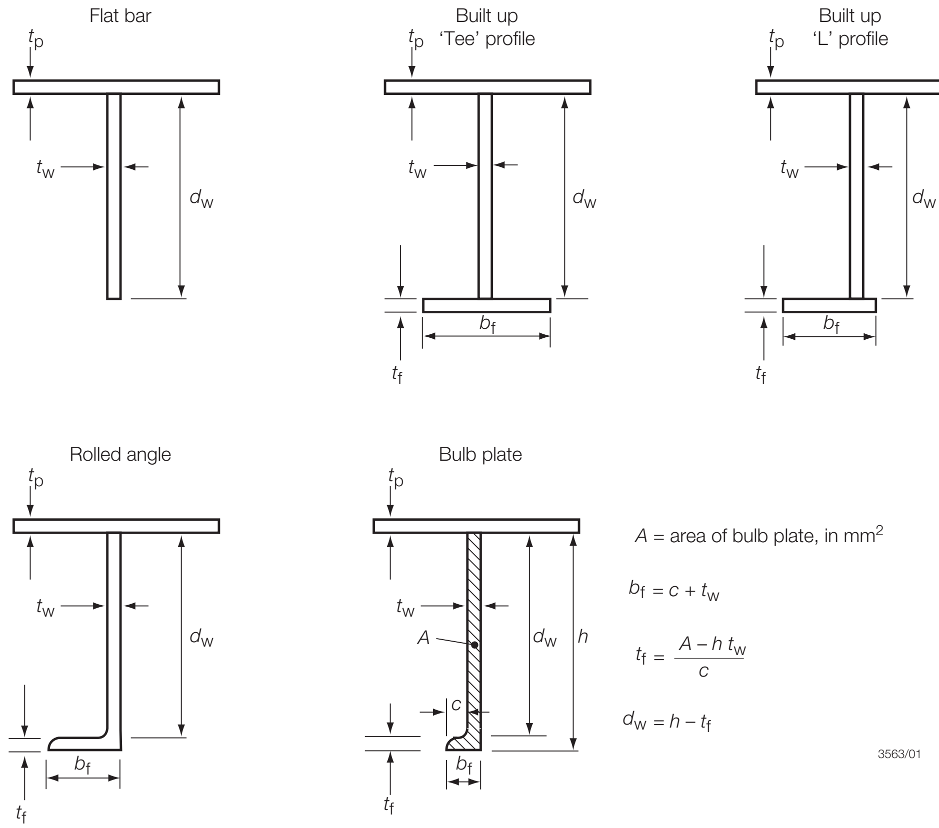


Fig. 7.4.4 Dimensions of longitudinals

Table 7.4.4 Buckling factor of safety

Structural item	Buckling factor of safety (2) Compressive stresses, λ_σ	Buckling factor of safety (3) Shear stresses, λ_τ
Bottom shell plating	1,0	–
Inner bottom plating	1,0	–
Deck plating	1,0	–
Side shell plating	1,0	1,1
Longitudinal bulkhead plating	1,0	1,1
Double bottom girders	1,0	1,1
Longitudinal girders	1,0	1,1
Superstructures/deckhouses (partially longitudinally effective)	1,0	–
Longitudinal secondary stiffeners	1,1(1)	–
Girder and floor web plating subject to local loads	1,1	1,2

NOTES
1. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25, *see also* 4.5.
2. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.
3. Buckling factor of safety to be applied to the shear stress.

■ *Section 5*
Vibration control

5.1 General

5.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

5.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with 5.3, 5.4 and 5.5, as appropriate. Under other circumstances finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

5.2 Frequency band

5.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

5.3 Natural frequency of plate

5.3.1 The natural frequency of a clamped plate in air is given by the following:

$$f_{air} = 5{,}544\,\frac{t_p}{ab}\sqrt{\left(\frac{a}{b}\right)^2 + \left(\frac{b}{a}\right)^2 + 0{,}6045}\quad \text{Hz}$$

where

a = panel length, in metres
b = panel breadth, in metres
t_p = panel thickness, in mm.

5.4 Natural frequency of plate stiffener

5.4.1 The natural frequency of a plate stiffener in air is given by the following:

$$f_{air,i} = \frac{K_i}{2\pi\,L_b^2}\sqrt{\frac{E\,I}{m\left(1 + \dfrac{\pi^2\,E\,I}{L_b^2\,GA}\right)}}\quad \text{Hz}$$

where

$E\,I$ = flexural rigidity of plate stiffener combination, in Nm^2
GA = shear rigidity of plate stiffener combination, in N
L_b = beam length, in metres
m = mass per unit length of the stiffener and associated plating, in kg/m
K_i = constant where i refers to the mode of vibration as given in Table 7.5.1.

Table 7.5.1 Vibration mode constant K_i

Mode	1	2	3	4	5
K_i	22,40	61,70	121,0	200,0	299,0

5.5 Effect of submergence

5.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air, f_{air}, may be modified by the following formula:

$$f_{water} = \psi\,f_{air}$$

where

$$\psi = \sqrt{\frac{\kappa_p}{\kappa_p + \dfrac{\rho_l}{\rho_p}}}$$

ρ_l = density of the liquid, in kg/m^3
ρ_p = density of the plate, in kg/m^3

$$\kappa_p = \frac{\pi\,t_p}{1000a\,b}\sqrt{a^2 + b^2}$$

where

a, b and t_p are as defined in 5.3.1.

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Part 8

Hull Construction in Composite

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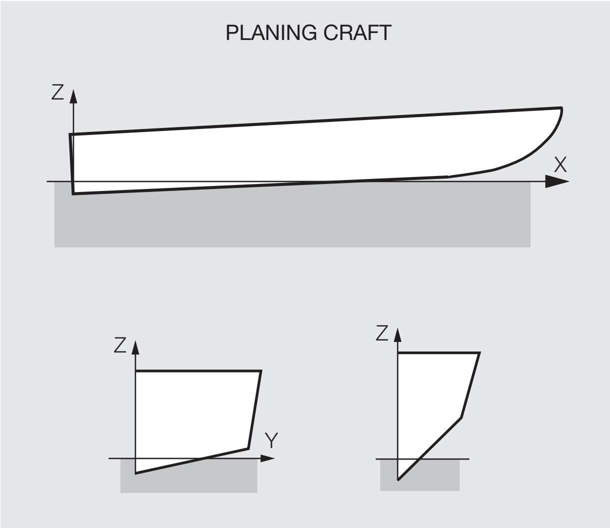
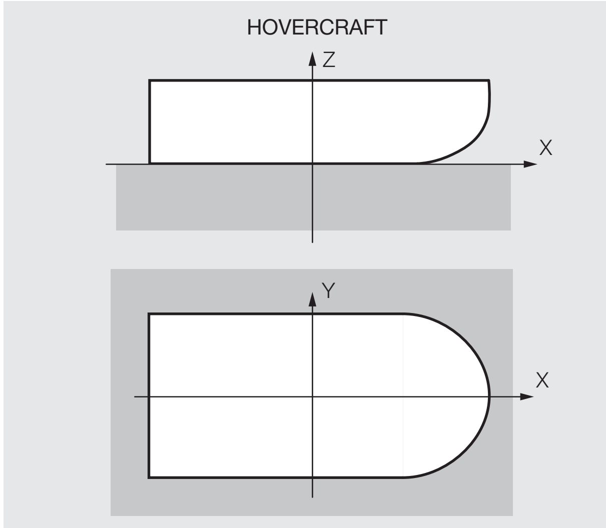
LIFE MATTERS

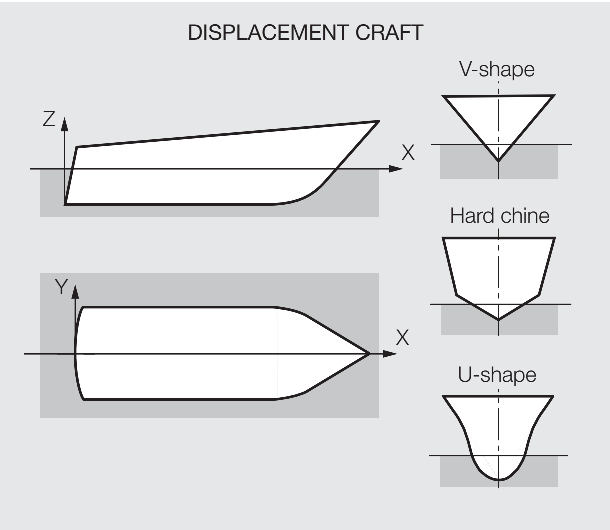
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES



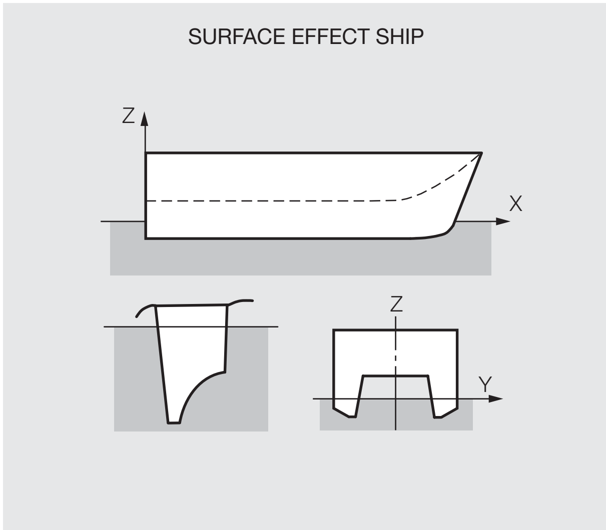
PLANING CRAFT



HOVERCRAFT



DISPLACEMENT CRAFT



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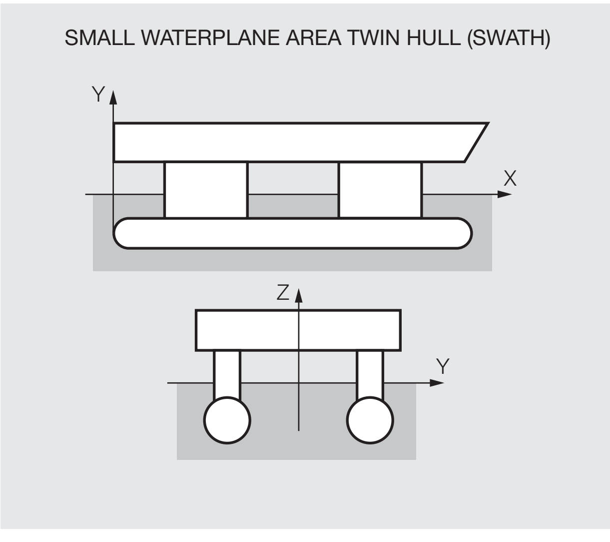
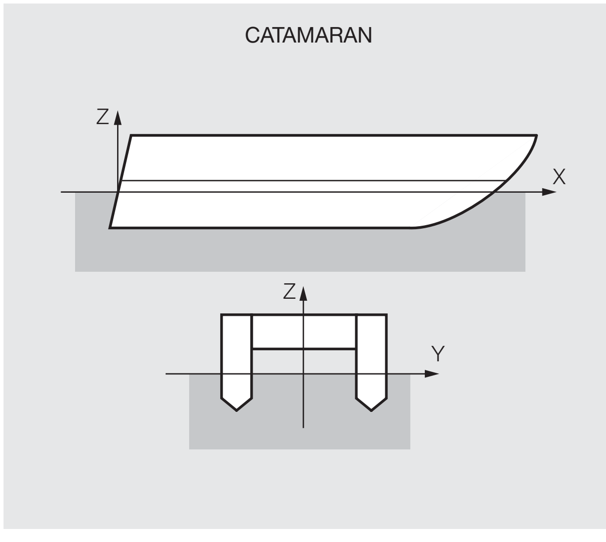
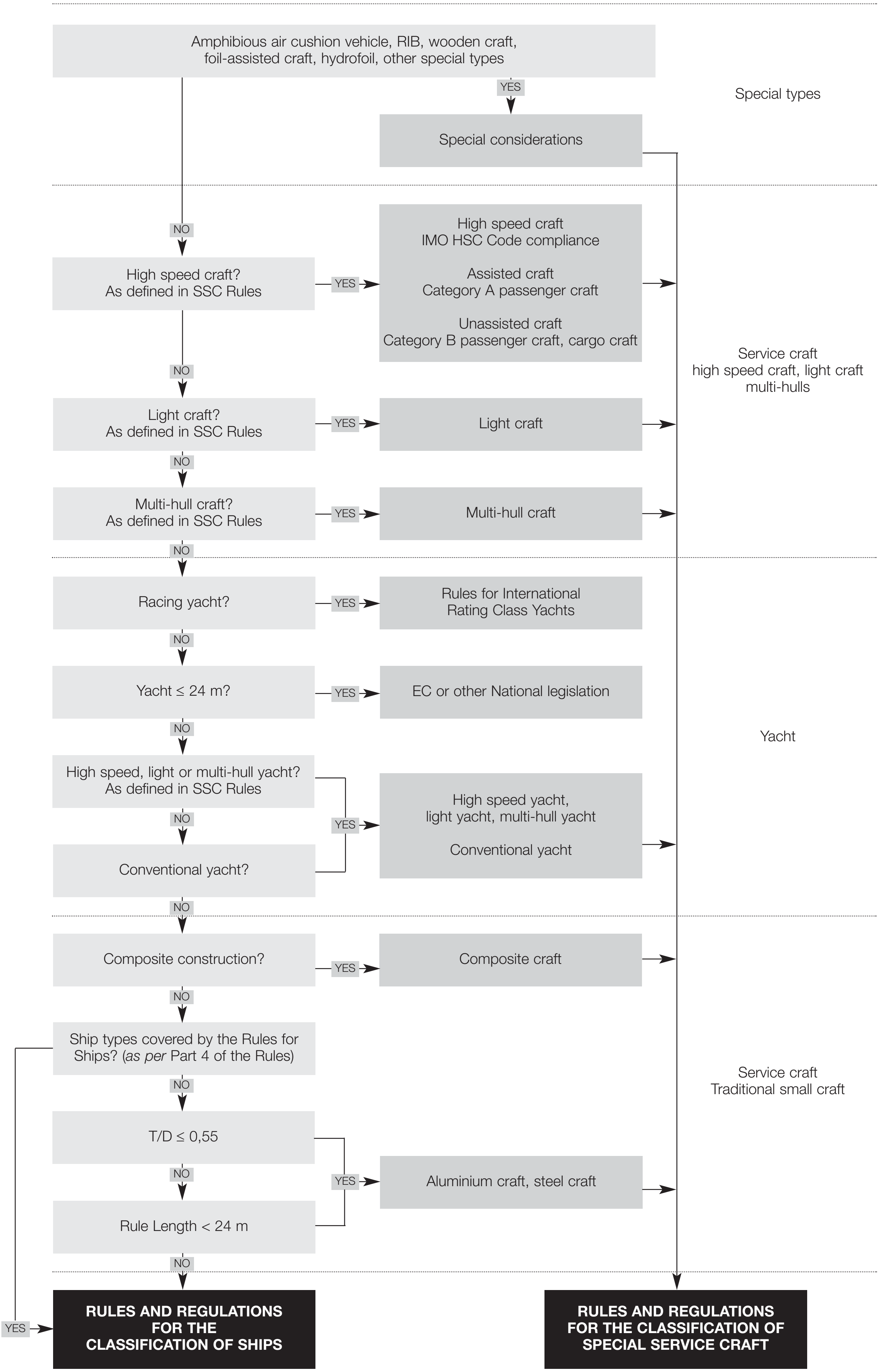


SMALL WATERPLANE AREA TWIN HULL (SWATH)



CATAMARAN

DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



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Section 1
Application

1.1 General

1.1.1 The Rules are applicable to mono and multi-hull craft of normal form, proportions and speed. Although the Rules are, in general, for fibre reinforced composite craft of laminated construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 The Rules provide for craft of both single and sandwich skin construction.

1.2 Interpretation

1.2.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the Builder's and/or designer's responsibility to obtain clarification from LR prior to submission of plans and data for appraisal.

1.2.2 Where applicable, the Rules take into account unified requirements and interpretations established by the International Association of Classification Societies (IACS).

1.2.3 Attention is drawn to the fact that Codes of Practice issued by IMO or other applicable National Authorities may contain requirements which are outside classification as defined in the Rules.

1.3 Equivalents

1.3.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with Pt 3, Ch 1,3.

1.4 Symbols and definitions

1.4.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

Section 2
General requirements

2.1 General

2.1.1 Specific limitations regarding the application of the Rules are indicated in the various Chapters for differing types of craft.

2.2 Aesthetics

2.2.1 LR is not concerned with the general arrangement, layout and appearance of the craft; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, and in this respect the acceptance criteria as required by the Rules are to be complied with.

2.3 Constructional configuration

2.3.1 The Rules provide for the basic structural configurations for both single and multi-deck mono and multi-hull craft with single or double bottom arrangements. The structural configuration may also include a single or multiple arrangement of cargo hatch openings and side tanks.

2.3.2 The Rules provide for longitudinal and transverse framing systems.

2.3.3 Novel or other types of framing systems will be considered on the basis of the Rules.

2.4 Plans to be submitted

2.4.1 Plans covering the following items are to be submitted:

- Midship sections showing longitudinal and transverse material.
- Profile and decks.
- Deck hatches.
- Bridging structure.
- Shell expansion.
- Laminate schedule.
- Oiltight and watertight bulkheads.
- Propeller brackets.
- Integral tanks.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Doors, hatches, windows and portlights.
- Deckhouses and superstructures.
- Sternframe.
- Rudder, stock and tiller.
- Anchoring and mooring equipment.
- Loading manuals, preliminary and final (where applicable).
- Ice strengthening.
- Welding (where applicable).
- Hull penetration plans.

- Support structure for masts, derrick posts or cranes.
- Bilge keels showing connections and detail design.
- Chain-plates.

2.4.2 The following supporting documents are to be submitted:
- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Sail/rigging plan, indicating loadings (as applicable to sailing craft).

2.4.3 The following supporting calculations are to be submitted, *see also* 2.7:
- Equipment Number.
- Hull girder still water and dynamic wave bending moment and shear force as applicable.
- Midship section stiffness.
- Structural items in the aft end, midship and fore end regions of the craft.
- Preliminary freeboard calculation.

2.5 Materials data sheet

2.5.1 Details of all the approved and accepted plastics materials, as required by the Rules, are to be submitted on LR's Reinforced Plastic Structures Materials Data Sheet (Form 2075) with the initial submission of plans. Reference is to be made to Ch 2,2. The types and quantities of curing systems identified on the Materials Data Sheet are to be those recommended by the resin manufacturer for the approved resin systems.

2.5.2 When specifying materials, the exact manufacturer's type designation, identification and reference numbers are to be quoted.

2.5.3 All sandwich core materials are to be of a type acceptable to LR and are to be clearly identified together with any core bonding adhesive to be used.

2.5.4 Fibre contents by weight for each type of reinforcement are to be reported.

2.5.5 All relevant post curing data is to be documented on the Materials Data Sheet.

2.6 Novel features

2.6.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the appropriate *Register Book*.

2.7 Direct calculations

2.7.1 Direct calculations may be specifically required by the Rules and may be required for craft having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of the designers and make recommendations in regard to suitability of any required model tests.

2.7.2 Where direct calculations are proposed then the requirements of Pt 3, Ch 1,2 are, in general, to be complied with.

2.8 Exceptions

2.8.1 Craft of unusual form, proportions or speed, intended for the carriage of special cargoes, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

2.9 Advisory services

2.9.1 The Rules do not cover certain technical characteristics, such as stability, except as mentioned in Pt 1, Ch 2,1.1.11, 1.1.13 and 1.1.14, trim, vibration, docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

Section 1
General requirements

1.1 General

1.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic in accordance with 2.1.1.

1.1.2 All construction is to be carried out using materials and techniques approved or accepted by Lloyd's Register (hereinafter referred to as 'LR'). Where non-approved or non-accepted materials or production techniques are proposed, it is the responsibility of the Builder and manufacturer to obtain the necessary approval or acceptance and demonstrate their equivalence on the basis of the Rules.

1.1.3 It is the Builder's responsibility to ensure that all materials are used in accordance with the manufacturer's instructions.

1.2 Definitions

1.2.1 Definitions for use throughout this Chapter are as indicated in the appropriate Sections.

1.3 Symbols

1.3.1 Symbols for use throughout this Chapter are as indicated in the appropriate Sections.

1.4 Builder's facilities

1.4.1 Sections 1.4 and 1.5 are applicable to the facilities and works for the craft under survey.

1.4.2 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are to comply with any local or National Authority requirements.

1.4.3 Workshops and equipment are to be in accordance with good manufacturing practice and are to be to the satisfaction of the Surveyor.

1.4.4 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of production the facilities are to be inspected to the satisfaction of the attending Surveyor. This is to include evidence that the mandatory minimum quality control requirements as outlined in 1.6 and Ch 14,5 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), are fulfilled.

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to mould craft to the standards required by the Rules.

1.5.3 The Builder is to rectify any deficiencies to the Surveyor's satisfaction prior to the commencement of production.

1.5.4 The validity of the acceptance of the Builder's works for moulding craft under LR survey is subject to an annual QC audit and monitoring by the attending Surveyor. Where there is a break in the continuity of moulding under LR survey, the facilities will in general, be subject to an additional inspection prior to any recommencement of any moulding carried out under LR survey.

1.5.5 For acceptance the survey is to include procedures covering the Builder's management, organisation and quality systems.

1.6 Quality control

1.6.1 The Builder's mandatory quality systems for composite construction, will be subject to inspection and audit, and are to be in accordance with the requirements of one of the following:

(a) Quality Assurance System in accordance with an International or National Standard (i.e., ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body and must reflect the minimum quality control requirements under (c) being complied with.

(b) LR's *Quality Assurance Scheme for the Construction of Special Service Craft*.

(c) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the activities as indicated below, *see also* Ch 14,5 of the Rules for Materials:
   - (i) Receipt storage and issue of materials, equipment, etc.
   - (ii) Moulding shop.
   - (iii) Care and preparation of mould tools, etc.
   - (iv) Lay-up process control.
   - (v) Inspection of FRP mouldings on release.
   - (vi) Installation of machinery and essential systems.
   - (vii) Fitting-out.
   - (viii) Tests and trials.
   - (ix) Plans and document control.
   - (x) Records.

1.6.2 LR's involvement is only in that part of the system which controls the standards required to meet the classification requirements.

1.6.3 The mandatory 'documented' quality control system, in general, requires the Builder to have written down procedures that describe clearly and unambiguously how each of the above activities is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled covering formal issue and revision.

1.7 Moulding shop

1.7.1 Where the conventional hand lay-up or spray lay-up processes are used, an even shop temperature of not less than 16°C, and, in general, of not more than 25°C, is to be maintained throughout the moulding area during the lay-up and curing periods. Where the temperature exceeds 25°C, special consideration is to be given to the resin system.

1.7.2 Where moulding processes other than those in 1.7.1 are to be used, the moulding shop temperature will be subject to individual consideration in conjunction with the written recommendations of the manufacturers of the materials.

1.7.3 The relative humidity in the moulding shop is to be kept below 70 per cent, taking into account the dew point, thus avoiding moisture condensation on moulds and materials.

1.7.4 Sufficient temperature and humidity monitoring equipment is to be provided and detailed records are to be kept in accordance with the quality control system.

1.7.5 It is the responsibility of the Builder to ensure that the ventilation and working conditions, together with discharges into the atmosphere, are such that levels of substances are within the limits specified in any pertinent National or International legislation.

1.7.6 The working areas are to be adequately illuminated. Precautions are to be taken to avoid any effects on the resin cure due to direct sunlight or artificial lighting.

1.8 Storage areas

1.8.1 The resins are to be stored under dry, well-ventilated conditions, in accordance with the manufacturer's recommendations.

1.8.2 Where resin tanks or drums are stored outdoors it is the Builder's responsibility to ensure that the resin manufacturer's storage conditions are complied with.

1.8.3 Where the temperature for materials storage drops below that of the moulding shop i.e. minimum 16°C, the materials are to be pre-conditioned to the moulding shop temperature prior to use.

1.8.4 Curing agents are to be stored separately under clean, dry and well-ventilated conditions in accordance with the manufacturer's recommendations and any local or National legislation.

1.8.5 Fillers and additives are to be stored in closed containers that are impervious to dust and moisture.

1.8.6 Reinforcements are to be stored under dust-free and dry conditions.

1.9 Mould construction

1.9.1 Moulds are to be constructed of a suitable material and are to be adequately stiffened to maintain their overall shape and fairness of form.

1.9.2 The materials used in the construction of moulds are not to affect the resin cure.

1.9.3 The finish on a mould is to be such that the mouldings produced are suitable for the purpose intended. The resultant aesthetic appearance of the moulding is strictly a matter between the moulder and the Owner.

1.9.4 Where multiple section moulds are used, the sections are to be carefully aligned to the attending Surveyor's satisfaction prior to moulding. Mismatch between mould sections is to be eliminated.

1.9.5 Where metallic moulds are used, welding is to be minimised to avoid distortion of panels.

1.9.6 The release agent is to be of a type recommended by the resin manufacturer and is not to affect the cure of the resin.

1.9.7 Prior to use all moulds are to be conditioned to the workshop temperature.

1.10 Materials handling

1.10.1 The arrangements for the receipt, verification against certificates of conformity and subsequent handling of materials are to be covered by the Builder's quality control procedures such that the materials do not suffer contamination or degradation and bear adequate identification at all times; *see* Ch 14,3 of the Rules for Materials. Storage is to be arranged such that materials are used by batch wherever possible, in order of receipt. Materials are not to be used after the manufacturer's date of expiry, except with the prior agreement of LR and new certificates of conformity being obtained from the material manufacturer. Details of the new certificates of conformity are to be entered into the quality control system.

1.10.2 Where materials are found to be non-conforming they are to be rejected in accordance with the Builder's quality control procedure.

1.10.3 All non-conforming materials are to be segregated in their storage areas and marked accordingly.

1.10.4 Resin/catalyst pumps and spray equipment are to be operated in accordance with the manufacturers instructions. Maintenance and calibration of the mix ratio is to be carried out according to written procedures.

1.11 Faults

1.11.1 All faults are to be classified according to their severity and recorded, together with the remedial action taken, under the requirements of the quality control systems, the documentation being subject to review at the Periodical Survey.

1.11.2 Production faults are to be brought to the attention of the attending Surveyor and a rectification scheme agreed. Deviations from the approved plans are to be to the satisfaction of the attending Surveyor.

1.12 Inspection

1.12.1 It is the Builder's responsibility to carry out the required inspections in accordance with the accepted quality control system.

1.12.2 The Surveyor will monitor the Builder's quality control records and carry out inspections of work in progress during his periodical visits.

1.12.3 During inspections all deviations are to be dealt with under the Builder's agreed quality procedures, *see* 1.6.3.

1.13 Acceptance criteria

1.13.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality system.

1.13.2 The workmanship is to be to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.13.3 Proposed deviations from the approved plans are subject to LR approval. An amended plan is to be submitted to the plan appraisal office, prior to any such changes being introduced.

1.14 Repair

1.14.1 Minor repairs are to be agreed with the attending Surveyor prior to being carried out. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with 1.6.3.

1.14.2 Written details of proposed structural repairs are to be submitted to the Plan Approval Office for approval prior to introduction.

1.15 Scaffolding

1.15.1 Scaffolding/platform arrangements are to be provided to permit adequate access for production and inspection purposes. Such arrangements are to conform to National Authority requirements and are not, in general, to be connected to the moulding or impinge on the mould surface.

1.16 Access

1.16.1 The attending Surveyor is to be permitted reasonable access to all areas of the Builder's premises during normal working hours. Scaffolding/platform arrangements are to be made available in accordance with 1.15.

1.17 Lifting arrangements

1.17.1 Lifting arrangements are to be designed such that mouldings are subjected to minimal distortion and unnecessary stressing. Mouldings are to be adequately supported to avoid distortion during final cure.

■ *Section 2* **Materials**

2.1 General

2.1.1 The Rules are applicable to craft generally constructed of fibre reinforced plastic (typically with unsaturated polyester resin), using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both.

2.1.2 Other materials (i.e., non-FRP materials) are to be of good quality, suitable for the purpose intended and, where applicable, are to comply with LR's requirements appropriate to the material. Details of these materials are to be stated on the relevant construction plans. Where these materials are attached to, or encapsulated within, the plastics construction, the material is not to affect adversely the cure of the plastics materials.

2.1.3 Where moulding techniques and methods of construction differing from those given in Section 3 are proposed, details are to be submitted for consideration by LR.

2.2 Resin system

2.2.1 The resins used are to be of a type that has been approved by LR for marine construction purposes. Samples of the resin batches being used in the construction may be taken for limited quality control examination at the discretion of the Surveyor, *see* Ch 14,5 of the Rules for Materials.

2.2.2 The cure procedure for the resin system is to be that recommended by the resin manufacturer for the particular application, so that the resin will cure in the required time, in accordance with the approved cure schedule.

2.2.3 Wax additives are only to be added by the resin manufacturer in accordance with the agreed procedure and tested accordingly. The base resin is to be of an approved type.

2.2.4 Where a resin contains an ingredient that can settle within the resin system, it is the Builder's responsibility to ensure that the resin manufacturer's recommendations regarding mixing and conditioning are complied with prior to use.

2.3 Compliant resins

2.3.1 Compliant resins for structural applications are to be of types accepted by LR, *see* Ch 14,2.15 of the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.3.2 Details of the compliant resin to be used in the construction are to be included on the Material Data Sheet at the initial stages of plan approval. The plans submitted for approval are to identify which compliant resins are used in different applications. Surface preparations and over-bonding are also to be identified on the submitted plans.

2.3.3 Proposals for the use of structural filleting applications using compliant resin are to be submitted in detail. Such proposals will be subject to individual consideration.

2.3.4 The acceptance of the use of structural fillets of compliant resins in place of boundary bonding angle laminates required by Ch 3,1.18, will be subject to the designer/Builder providing the necessary information and test results to demonstrate equivalence with the Rule requirement for boundary bonding angle laminates.

2.3.5 Air inclusions that may affect the structural efficiency of the joint are to be avoided.

2.4 Resin storage

2.4.1 Bulk storage of resin is to be arranged in accordance with the resin manufacturer's recommendations in suitably adapted and insulated tanks. Tanks and pipes are to be periodically flushed in accordance with the resin manufacturer's recommendations. A ready use store is to be provided where appropriate.

2.5 Gel coats, tie coats and water barriers

2.5.1 Gel coats based on orthophthalic polyester resin systems are not acceptable. All gel coats are to be used strictly in accordance with the manufacturer's recommendations. The curing system is to be in accordance with 2.2.2.

2.5.2 Where pigments are to be added reference is to be made to 2.6. Where pigments are added by the Builder, the gel coat is to be allowed to stand for sufficient time to permit entrapped air to be released. The method of mixing is to be carried out strictly in accordance with the resin and pigment manufacturer's instructions.

2.5.3 Where the temperature of the gel coat resin is below that of the workshop, the gel coat resin is to be conditioned to attain the workshop temperature prior to use.

2.5.4 Where the inspection of the mould is an agreed hold point, required by the quality plan, the mould is to be inspected by the attending Surveyor prior to gel coating. The Surveyor may also require to witness the initial application of the gel coat, *see also* 3.3.

2.5.5 Where a gel coat is not used, details of the proposed water barrier are to be submitted for consideration.

2.5.6 Where a painted finish is to be adopted in place of a gel coat a suitable tie coat may be required in accordance with the paint manufacturer's recommendations.

2.5.7 Where the hull is of sandwich construction built on a male plug mould, the water barrier on the outer surface of the hull will be specially considered.

2.6 Curing systems

2.6.1 Curing systems are to be in accordance with 2.2.2 and are to be fully compatible with the resins and reinforcements to be used.

2.6.2 For polyester and vinylester resins the level of catalyst and accelerator are to be as recommended by the manufacturer to ensure full polymerisation of the resin. In general, the rate of gelation is to be controlled by the amount of accelerator added to the resin. The amount of catalyst is not to be less than one per cent, by weight, of the base resin.

2.7 Gelation time

2.7.1 The gelation time is to be suitable for the proposed application such that full wet-out of the reinforcement can be obtained without unnecessary drainage on vertical surfaces or excessive loss of the monomer.

2.7.2 The gelation time quoted on the Material Data Sheet is to be the typical gelation time for a laminate as laid in the mould, i.e., the working life of the resin.

2.7.3 The gelation time may need to be varied to suit changing ambient workshop temperatures. For polyester and vinylester resins this is, in general, to be adjusted by variation of the accelerator and not by variation of the catalyst.

2.7.4 All resins are to be mixed in accordance with the resin manufacturer's recommendations.

2.8 Colour pigments

2.8.1 The types of pigment used are to be such that the final cure of the resin is not affected.

2.8.2 The pigment may be added to the resin by either the resin manufacturer or the moulder, and when added by the moulder it is to be as a paste dispersal in the same or compatible resin. Pre-pigmented gel coats are recommended. Where pigments are added by the Builder thorough mixing is essential to avoid striations. *See also* 2.2.4 and 2.3.2.

2.8.3 The amount and type of pigment added is not to exceed that recommended by the resin manufacturer for a satisfactory depth of colour. Proposals to use amounts of pigment solids in excess of five per cent, by weight of the base resin, will be subject to individual approval and testing.

2.8.4 It is recommended that pigments are not to be added to the gel coat or laminating resins used in the underwater portion of the hull laminate or in laminates forming the boundaries of oil fuel and water tanks.

2.8.5 The addition of pigments is not to unduly affect the gelation time of the resin system or the physical properties of the gel coat layer of the laminate produced. The resin and/or pigment manufacturer's written confirmation in this respect is to be obtained and recorded in the Builder's quality control documentation.

2.8.6 The aesthetic appearance of mouldings is strictly a matter between the moulder and the Owner.

2.9 Fillers

2.9.1 All fillers added by a Builder are to be of the dispersed type. The amount of filler that may be added to an approved resin is to be that recommended by the resin manufacturer and is not to alter significantly the viscosity of the resin nor is it to affect the overall strength properties of the laminate. Recommendations by the resin manufacturer to adopt amounts of fillers in excess of 13 per cent by weight of the base resin will be subject to individual approval and testing.

2.9.2 Pigments, thixotropes and fire retardant additives are to be considered as fillers in the calculation of total filler content.

2.9.3 Fillers are to be carefully and thoroughly mixed into the base resin that is then to be allowed to stand to ensure that entrapped air is released. The resin manufacturer's recommendations regarding the method of mixing are to be followed.

2.9.4 Fillers are not to be used in the structural laminates forming the boundaries of oil fuel and water tanks.

2.9.5 Details of all fillers and fire retardant additives are to be included on the Material Data Sheet at the initial stages of plan appraisal.

2.9.6 The amount of fire retardant additives may be in excess of that indicated in 2.9.1 provided that due account is taken of the reduced mechanical properties when determining scantlings in accordance with the Rules.

2.10 Fire retardant additives

2.10.1 The attention of Owners and Builders is drawn to the additional statutory regulations regarding fire safety that may be imposed by the National Authority of the country in which the craft is to be registered or the Governments of the states to be visited.

2.10.2 For requirements regarding fire safety, *see* Part 17.

2.10.3 Where laminates are required to have fire retardant or restricting properties, details of the proposals are to be submitted for approval. Where additives to the resin system are used, the type and quantity are to be as recommended by the resin manufacturer. Test results of independently tested fire retardant and fire restricting materials are to be submitted for design purposes.

2.10.4 All fire retardant resin systems are to be used strictly in accordance with the resin manufacturer's recommendations.

2.10.5 The use of fire retardant and fire restricting materials in craft required to comply with statutory requirements will be subject to the individual approval of the National Authority of the country in which the craft is to be registered, or LR where authorised to undertake this work on behalf of the National Authority.

2.11 Fibre reinforcements

2.11.1 All fibre reinforcements are to be of a type approved by LR.

2.11.2 All reinforcements are to be stored strictly in accordance with the manufacturer's recommendations. Rolls of reinforcement are to remain in their original packaging to minimise contamination. The quality control documentation is to provide traceability of all reinforcements using the manufacturer's batch numbers.

2.11.3 The materials are to be free from imperfections, discolouration, foreign matter and other defects.

2.11.4 Pre-impregnated reinforcements are to be suitably stored in an approved area. Detailed storage records are to be maintained as part of the quality control documentation.

2.12 Surfacing materials

2.12.1 Lightweight surfacing materials for reinforcing resin rich surfaces are to be compatible with the resin being used. Details of the materials and the fibre contents, by weight, are to be included on the Materials Data Sheet (Form 2075).

2.12.2 Where peel ply materials are to be used, the finish is to be such that, after removal, it does not interfere with any subsequent bonding processes.

2.13 Core materials

2.13.1 Core materials for sandwich construction are to be approved by LR, *see* Ch 14,2 of the Rules for Materials.

2.13.2 All core materials are to be used in accordance with the manufacturer's application procedure, a copy of which is to be submitted for information, with the relevant construction plans of the craft. A second copy is to be incorporated into the quality control documentation.

2.13.3 Rigid expanded foam plastics are to:
(a) be of closed-cell types and impervious to water, fuel and oils;
(b) have good ageing stability;
(c) be compatible with the resin system;
(d) have good strength retention at 60°C;
(e) have characteristics and mechanical properties of not less than those indicated in Table 2.2.1; and
(f) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.4 Balsa wood is to:
(a) be end grained;
(b) have been chemically treated against fungal and insect attack and kiln dried shortly after felling;
(c) have been sterilised;
(d) have been homogenised;
(e) have an average moisture content of 12 per cent;
(f) have characteristics and mechanical properties of not less than those indicated in Table 2.2.2; and
(g) if manufactured into formable sheets of small blocks, the open weave backing material and adhesive are to be compatible and soluble, respectively, with the laminating resin.

2.13.5 Where necessary, foam core materials are to be conditioned in accordance with the manufacturer's recommendations. Conditioning at an elevated temperature, in excess of that which may be experienced in service, may be necessary to ensure the release of any entrapped residual gaseous blowing agents from the cells of the foam core.

2.13.6 Synthetic 'felt' type core materials are to be approved in accordance with Ch 14,2.10 of the Rules for Materials.

2.13.7 Other types of core materials will be individually considered, on the basis of these Rules in relation to their characteristics and intended application.

2.13.8 Balsa wood is to remain in protective packaging until required in production. Part packages are to be sealed to prevent the ingress of moisture.

Table 2.2.1 Minimum characteristics and mechanical properties of rigid expanded foams at 20°C

<table>
<tr><th rowspan="2">Material</th><th rowspan="2">Apparent density (kg/m³)</th><th colspan="3">Strength (N/mm²)</th><th colspan="2">Moduli of elasticity (N/mm²)</th></tr>
<tr><th>Tensile</th><th>Compressive</th><th>Shear</th><th>Compressive</th><th>Shear</th></tr>
<tr><td>Polyurethane</td><td>96</td><td rowspan="2">0,85</td><td rowspan="2">0,60</td><td rowspan="2">0,50</td><td rowspan="2">17,20</td><td rowspan="2">8,50</td></tr>
<tr><td>Polyvinylchloride</td><td>60</td></tr>
</table>

Table 2.2.2 Minimum characteristics and mechanical properties of end-grain balsa

<table>
<tr><th rowspan="4">Apparent density (kg/m³)</th><th colspan="5">Strength (N/mm²)</th><th colspan="2" rowspan="2">Compressive modulus of elasticity (N/mm²)</th><th rowspan="4">Shear modulus of elasticity (N/mm²)</th></tr>
<tr><th colspan="2">Compressive</th><th colspan="2">Tensile</th><th rowspan="3">Shear</th></tr>
<tr><th colspan="4">Direction of stress</th><th colspan="2">Direction of stress</th></tr>
<tr><th>Parallel to grain</th><th>Perpendicular to grain</th><th>Parallel to grain</th><th>Perpendicular to grain</th><th>Parallel to grain</th><th>Perpendicular to grain</th></tr>
<tr><td>96</td><td>5,00</td><td>0,35</td><td>9,00</td><td>0,44</td><td>1,10</td><td>2300</td><td>35,20</td><td>105</td></tr>
<tr><td>144</td><td>10,60</td><td>0,57</td><td>14,60</td><td>0,70</td><td>1,64</td><td>3900</td><td>67,80</td><td>129</td></tr>
<tr><td>176</td><td>12,80</td><td>0,68</td><td>20,50</td><td>0,80</td><td>2,00</td><td>5300</td><td>89,60</td><td>145</td></tr>
</table>

2.14 Core bonding materials

2.14.1 Core bonding materials for structural applications are to be of types accepted by LR, and are to be used strictly in accordance with the manufacturer's instructions.

2.14.2 Details of the proposed core bonding paste to be used with the core material are to be indicated on the Materials Data Sheet and the appropriate construction plans.

2.14.3 The Builder is to demonstrate that a uniform thickness of bonding paste is obtained by use of notched trowels or comb gauges. For the use of bonding pastes, *see* 4.2.7.

2.15 Adhesives

2.15.1 Adhesives for structural applications are to be of types accepted by LR, *see* Ch 14,2.15 the Rules for Materials, and are to be used strictly in accordance with the manufacturer's recommendations.

2.15.2 The details of all structural adhesives are to be specified on the Materials Data Sheet and on the relevant construction plans submitted.

2.15.3 Details concerning the handling, mixing and application of adhesives are to form part of the Builder's production plan.

2.15.4 Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded.

2.15.5 Where excessive unevenness of the faying surfaces exists a suitable gap filling adhesive is to be used or local undulations removed by the application of additional reinforcements.

2.15.6 The Builder's quality plan is to identify the level of training required for personnel involved in the application of structural adhesives.

2.16 Materials for integrated structural members

2.16.1 Metallic materials (such as suitable marine grades of stainless steel or aluminium alloys) used in the construction are to comply with the requirements of 2.1.2. Where structural members or components manufactured from these, or other materials, are to be encapsulated within or structurally bonded to laminates, the material is not to adversely affect the cure of the resin system. The surface area of the component that will be in contact with the resin is to be thoroughly cleaned, degreased and, where practicable, either shot blasted or abraded to provide a key.

2.16.2 Where metallic sections are to be bolted into a structure, the bolting requirements are to be determined by direct calculations that are to be submitted for consideration. Appropriate precautions against corrosion are to be taken.

2.16.3 Where plywood and timber members are to be used in structural applications and are to be laminated onto, or encapsulated within the laminate, the surface of the wood is to be suitably prepared and primed prior to laminating.

2.17 Plywood

2.17.1 Plywood, for structural applications, is to be of a high quality marine grade material approved by LR, *see* Ch 14,2.14 of the Rules for Materials. In general, the plywood is to be manufactured to a high standard of finish in accordance with ISO or other Recognised Standards and is to meet, or be equivalent to, the following general requirements:

(a) Have good quality face and core veneers of a durable hardwood species.
(b) The number of veneers is to be in accordance with Table 2.2.3.
(c) The veneers are to be bonded with a WBP (water and boil proof) type adhesive.
(d) Have a moisture content not exceeding 15 per cent.

Table 2.2.3 Number of veneers

Board thickness, mm	Minimum number of plies
up to 9	3
10 to 19	5
20 and above	7

2.17.2 Butts and seams are to be scarfed or butt strapped where necessary. The length of the scarf is to be not less than eight times the plywood thickness. The scarf is to be glued and, if made *in situ*, fitted with a backing strap of width not less than 10 times the panel thickness. The strap is to be glued and fastened with two rows of fastenings of the size given in Table 2.2.4 and spaced at approximately eight times the panel thickness.

2.17.3 Butt straps are to be of the width given in Table 2.2.4 and the same thickness as the panel. The strap is to be glued and double/treble fastened to the panel. Sizes of fastenings are given in Table 2.2.4.

2.17.4 For further information regarding plywood, *see* Ch 3,1.20.

2.18 Timber

2.18.1 The acceptance of timber in the construction will be subject to individual consideration depending upon the intended use and timber involved.

2.18.2 The timber is to be of good quality and properly seasoned. Timber is to be free from heart, sapwood, decay, insect attack, splits, shakes and other imperfections that would adversely affect the efficiency of the material. It is also to be generally free from knots, although an occasional sound intergrown knot would be acceptable.

Table 2.2.4 Butt strap fastenings

Plywood thickness, mm	Breadth of butt strap, mm		Fastenings: Wood screws, Gauge	Fastenings: Wood screws, Dia.,mm	Fastenings: Copper boat nails, gauge
6	Double fastened	150	8	4,2	10
8	Double fastened	175	10	4,9	10
10	Double fastened	200	10	4,9	8
13	Double fastened	250	12	5,6	8
16	Double fastened	280	12	5,6	6
19	Treble fastened	330	14	6,3	6
22	Treble fastened	355	14	6,3	3
25	Treble fastened	380	16	7,0	3

NOTES
1. The gauge of wood screws given in the Table is British Standard Gauge, and that of copper boat nails is Imperial Standard Wire Gauge.
2. The diameter of the wood screw is the nominal diameter of the unthreaded shank.

2.18.3 The moisture content of timber for bonded or over-laminated applications using polyester or epoxy resins is, in general, to be nominally 15 per cent. Contents slightly greater than this value are recommended when resorcinol glues are used, and contents slightly lower than this value are required when phenolic or urea-formaldehyde resins are used.

2.18.4 For further information regarding timber, *see* Ch 3,1.19.

2.19 Release agents

2.19.1 Release agents are to have no inhibiting effect on the gel coat resin and are to be those recommended by the resin manufacturer.

■ *Section 3* General construction process

3.1 General

3.1.1 Provision is made in this Section for the construction of craft built of fibre reinforced plastic using thermosetting materials. Craft built of fibre reinforced thermoplastic materials will be subject to individual consideration.

3.1.2 This Section contains the general Rule requirements to be complied with in the construction of fibre reinforced craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied.

3.1.3 Craft built of unusual materials or built using unusual techniques will be subject to individual consideration.

3.2 Resin preparation

3.2.1 Curing agents, fillers and pigments are to be added strictly in accordance with the resin manufacturer's recommendations.

3.2.2 Before decanting, all resins are to be thoroughly mixed, deaerated and conditioned to at shop temperature in accordance with the resin manufacturer's instructions.

3.2.3 All measuring equipment is to be certified and suitable for the quantity of material being measured. Valid certificates of calibration are to form part of the quality control documentation.

3.2.4 Where pumping/metering equipment is used it is to be maintained in accordance with the manufacturer's instructions, and a valid certificate of calibration accuracy is to be retained in the quality control documentation.

3.2.5 Quality control records are to be maintained to provide traceability and identification of the resin and all additives used in the resin system. Batch numbers are to be identified.

3.2.6 Any additive used as a production aid must be that recommended by the resin manufacturer and is not to alter the mechanical properties or the characteristics of the cured laminate.

3.3 Laminating

3.3.1 Production is to follow all necessary approved construction plans in accordance with the LR accepted quality plan.

3.3.2 Laminating is to be carried out by skilled operators, who are to be trained and qualified to the level required by the Builder's quality plan and are to be acceptable to LR.

3.3.3 Moulds are to be thoroughly cleaned, dried and allowed to attain the shop temperature before being treated with a suitable release system, *see also* 1.9.7.

3.3.4 The gel coat resin is to be applied by brush, roller or spraying equipment to give a uniform, nominal film thickness not exceeding 1,5 mm.

3.3.5 The period of exposure of the gel coat between gelation and the application of the first layer of reinforcement is, in general, to be as short as practicable. In no case is this to be longer than that recommended by the resin manufacturer for that particular resin system. Written confirmation of this is to be obtained and recorded in the Builder's quality control documentation.

3.3.6 Where a polyester or vinylester gel coat is used it is to be reinforced by a lightweight, powder bound reinforcement, generally not exceeding 300 g/m^2 in weight, applied at a high resin content to give a glass content, by weight, of not greater than 0,286. This reinforcement is to be consolidated by gentle rolling. Care is to be taken not to damage the gel coat. A surface tissue may be incorporated within the gel coat, the details of which are to be clearly stated in the laminate schedule.

3.3.7 All mouldings are to be manufactured from layers of reinforcement, laid in the approved sequence and orientation, each layer being thoroughly impregnated and consolidated to give the required fibre content, by weight, in accordance with the approved plans.

3.3.8 In composite laminates, containing multiple layers of woven reinforcement, woven reinforcement may be laid on woven reinforcement provided that the inter-laminar shear strength is not less than 13,8 N/mm^2; otherwise, a layer of random fibre reinforcement is to be laid alternately with the woven reinforcements.

3.3.9 Excessive exothermic heat generation caused by thick laminate construction is to be avoided. Where thick laminates are to be laid the Builder is to demonstrate to the Surveyor's satisfaction, that the number of plies can be laid wet on wet and that the resultant temperature during the cure cycle does not have any deleterious effect on the mechanical properties of the cured laminate.

3.3.10 Laminating is to be carried out in a sequence such that the time lapse between the application of the successive layers is within the limits recommended by the resin manufacturer and documented in the quality control procedures for the particular resin system. Similarly, the time lapse between the forming and bonding of structural members is to be kept within these limits and, where this is not practicable, the surface of the laminate is to be prepared, in accordance with the resin manufacturer's instructions, to improve the bond.

3.3.11 When laminating is interrupted, and where other than an epoxy resin system is being used, the first of any subsequent layers of reinforcement to be laid in that area is to be of chopped glass fibre or other type of material to enhance the interlaminar strength properties of the laminate.

3.4 Fibre content

3.4.1 To ensure that the resultant thicknesses of the structure is not less than that required to comply with those indicated on the approved plans, the nominal fibre content, by weight, of the individual plies and overall laminate is to be controlled on the basis of the weight of the constituent materials.

3.4.2 Continuous monitoring of resin/reinforcement usage is required for ongoing fibre content verification and is to be recorded under the quality control system, *see* Ch 14,5 of the Rules for Materials.

3.4.3 A method of validating the completed laminate thickness is to be agreed between the Builder and Surveyor. Where electronic thickness measurement methods are employed, the equipment is to be calibrated against a laminate of identical construction. Alternatively a series of areas are to be identified within the craft where samples can be taken to validate the thickness of the laminate (e.g., in way of overboard discharges/seawater intakes/deck openings, etc.).

3.5 Laminate schedule

3.5.1 The laminate schedule is to clearly define the logical sequence of production and is to identify the specific materials to be used.

3.5.2 The schedule is to define the extent of each reinforcement and state relevant details regarding overlapping, staggering thicknesses and tailoring of reinforcements.

3.5.3 Progressive thickness measurements in accordance with 3.4.3 are to be recorded as part of the quality control documentation and, where required, additional reinforcements are to be laid to attain the required thickness.

3.5.4 Areas of local deficiency requiring additional reinforcement and areas that have been found to be increased thickness are to be recorded in the quality control documentation.

3.6 Spray laminating

3.6.1 The equipment for spray deposition of resin and glass fibres is to be inspected during the Workshop Inspection and a sample panel produced. Documentary evidence of maintenance, calibration, catalyst content, fibre length and overall fibre content by weight are to be entered into the quality control documentation. The spray pattern is to give an even distribution, as recommended by the manufacturer of the equipment and is to be to the satisfaction of the attending Surveyor.

3.6.2 Special consideration is to be given to the production environment, ventilation equipment and quality control arrangements to ensure that the finished product meets the requirements of the approved plans.

3.6.3 Unless the mechanical properties are confirmed by testing, the chopped fibre length for a structural laminate is to be not less than 35 mm. In no case is the fibre length to be less than 25 mm.

3.6.4 Spray equipment is only to be operated by trained and competent personnel. Training certification is to form part of the quality control documentation. The use of spray lay-up is to be limited to the parts of the structure to which sufficient access can be obtained to ensure satisfactory laminating.

3.6.5 The weights of resin and reinforcement used is to be monitored continuously to check the glass/resin ratio. Samples are also be taken on a regular basis to validate the calibration of the equipment.

3.6.6 Where spray lay-up is used to back up the gel coat the weight of sprayed fibre is not to exceed 300 g/m^2, applied at a high resin content to give a glass content by weight, of not greater than 0,286. This should be consolidated by gentle rolling. This first layer of reinforcement is to be allowed to cure to a trimming state before proceeding with the remainder of the laminate.

3.6.7 Consolidation is to be carried out as soon as is practicable after spray deposition. In general, this is to be carried out when a weight of reinforcement equivalent to a thickness of 2–3 mm has been deposited. The thickness of the resulting laminate is to be periodically checked and recorded.

3.6.8 Particular attention is to be given to localised thinning of the laminate in way of chines, coamings, knuckles and openings. Further deposition may be required in such areas to compensate for any reduction in thickness. Alternatively, layers of other equivalent reinforcements may be laid to achieve the required local thickness.

3.7 Release and curing

3.7.1 After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure before being removed. This period can vary with ambient temperature, the type of resin and the complexity of the moulding, but is to be not less than 12 hours or that recommended by the resin manufacturer.

3.7.2 Care is to be exercised during removal from the mould to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage to and maintain the form of the moulding.

3.7.3 Where female moulds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to removal from the mould unless agreed otherwise on the approved construction schedule and plans.

3.7.4 Mouldings are not to be stored outside of the workshop environment until they have attained the stage of cure recommended by the resin manufacturer for that particular resin. Provision is to be made for mouldings to be protected against adverse weather conditions.

3.7.5 Mouldings are, in general, to be stabilised in the moulding environment for at least 24 hours, or that recommended by the resin manufacturer before the application of any special cure treatment, details of which are to be submitted for approval.

3.8 Barcol hardness

3.8.1 The degree of cure of mouldings is to be measured using a Barcol impressor model GYZJ 934-1 in accordance with BS 2782: Part 10: Method 1001: 1977 (1989) or other equivalent National or International Standard. Alternative equivalent standards of hardness measurement will be considered.

3.8.2 The hardness meter is to be regularly checked for calibration during use. A calibration certificate is to form part of the quality control documentation.

3.8.3 Removal from the mould is not to be attempted until a minimum Barcol reading recommended by the resin manufacturer or a value of 20 has been attained. Subsequently, the moulding is not to be moved outside of the controlled environment until a minimum Barcol reading recommended by the resin manufacturer of 35 (or equivalent) has been recorded.

3.9 Laminate detail

3.9.1 Changes in laminate thickness are to be made using a gradual taper. The length of such taper is, in general, not to be less than 20 times the difference in thickness. Where the construction changes from sandwich laminate to a solid laminate, the thickness of the core material is, in general, to be reduced by a gradual taper of not less than 2:1.

3.9.2 Framing and stiffening sections are to be built up layer by layer in accordance with an approved procedure, particular attention being given to ensure a satisfactory bond and structural continuity at the ends and intersections.

3.9.3 Discontinuities and hard points in the structure are to be avoided, and where the strength of a stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc., compensation is to be provided.

3.9.4 Where items are prefabricated outside the mould, they are to be connected by boundary angles formed by layers of reinforcement, structural fillets or other approved method. Where structural fillets are proposed, the scantlings and arrangements will be specially considered.

3.9.5 Polyester, vinylester or epoxide resin may be used in bonded joints, provided that the joint is so designed that the resin bond is in shear. The contact area is to be as large as practicable and the surfaces are to be suitably prepared in accordance with the resin manufacturer's instructions.

3.9.6 The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.

3.9.7 The submitted plans are to clearly define the details of scarfed joints. In general, scarfs are not to not be steeper than a 12:1 taper. Scarf joints may be either ground or stepped and may be single or double taper. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.

3.9.8 Lap joints may be bolted or adhesively bonded, or both. They may be single or double lapped dependent upon the specific application.

3.9.9 Where tray mouldings form part of the integral structure of the craft, full details are to be indicated on the submitted plans. Information regarding tolerances is to be presented together with details of all adhesives and proposed bonding-in techniques. Particular attention is to be given to the design so as to maintain the structural continuity of the webs of any stiffening members.

3.9.10 The hulls of all craft with a service speed of 25 knots or greater are to be moulded as required by Ch 3,3.15.

3.9.11 Chine details are to be clearly indicated on the submitted plans. Spray rails may form part of the structural laminate or may be installed as a laminated or bolted appendage. Where the chine is a laminated appendage, provision is to be made for a sacrificial ply at which failure may occur without undue damage to the remaining structure of the hull. Sandwich structures are to be returned to single skin laminates at chine rails unless agreed otherwise on the approved construction plans. Chine rails are to be infilled and over laminated on the inner surface of the hull. Additional reinforcement is to be laminated into the chine area in accordance with Ch 3,3.8.

3.9.12 Reinforcements are to be arranged to maintain continuity of strength throughout the laminate. Joints in each layer of reinforcement are, in general, to be overlapped. The length of the overlap is dependent upon the type of reinforcement but is not to be less than 50 mm. The position of the joints in the laminate is to be staggered, in general by 150 mm, to maintain as near uniform laminate thickness as practicable. Tests may be required to demonstrate continuity of strength when bi-directional, multi-axial or cross plied reinforcements are used.

3.9.13 As an alternative to overlapping as required by 3.9.12, individual consideration will be given, on the basis of test results, to partial butting of reinforcements manufactured with a salvedge. For such reinforcements the salvedge tails are to be laid on top of each other to provide continuity. Butts in the same vertical plane are to be separated by not less than five passing plies.

3.9.14 Laminate overlapping and staggering arrangements may require to be tested at the discretion of the Surveyor.

3.9.15 Laminates may be fastened mechanically provided that the fastenings are of a corrosion resistant metal and are spaced and positioned so as not to impair the efficiency of the joint. The fastenings are to be of an acceptable type and, where washer plates are used, they are to be of a compatible material. The edges of the laminates and the fastening holes are to be sealed.

3.9.16 Where plywood and timber members are to be matted onto, or encapsulated within, the laminate, the surface of the wood is to be suitably prepared prior to bonding.

3.9.17 For details of through hull fittings, *see* 5.6.

■ *Section 4* Additional procedures for sandwich construction

4.1 General

4.1.1 The methods used in sandwich construction are, in general, to be either wet or dry core bonding techniques or by laminating directly onto the core (e.g., plug moulding).

4.2 Laminating

4.2.1 The forefoot and stem of all craft of composite construction are to be moulded as required by Ch 3,5.11.1.

4.2.2 Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.

4.2.3 Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, the Surveyor may request additional building up of the surface or contouring of the core to suit.

4.2.4 Where other than epoxy resins are being used, the reinforcement against either side of the core is to be of the chopped strand mat type. Additional flow coating is not to be applied to the foam core prior to laminating.

4.2.5 The submitted plans are to clearly show the staggering of successive plies in both the transverse and longitudinal directions. In general laminates are to be staggered by 50 mm per layer of reinforcement. Where very thin sandwich skins are adopted the rate of laminate stagger will be individually considered.

4.2.6 Prior to bonding, the core is to be cleaned and primed (sealed) in accordance with the manufacturer's recommendations. The primer is to be allowed to cure and is not to inhibit the subsequent cure of the materials contained within the manufacturer's recommended bonding process. The primer is to seal the panels, including all the surfaces between the blocks of contoured material, without completely filling the surface cells.

4.2.7 Where panels of rigid core material are to be used then dry vacuum bagging techniques are, in general, to be adopted. The core is to be prepared by providing 'breather' holes to ensure efficient removal of air under the core. Bonding paste is to be visible at such breather holes after vacuum bagging. The number and pitch of such 'breather' holes is to be in accordance with the core manufacturer's application procedure and any specific requirements of the core bonding paste manufacturer, *see also* 4.4.3.

4.2.8 Thermoforming of core materials is to be carried out in accordance with the manufacturer's recommendations. Maximum temperature limits are to be strictly observed.

4.2.9 Where panels of contourable core material are to be used it is necessary to ensure that the core is cut/scored through the entire thickness such that the panels will conform to the desired shape of the moulding. The Builder is to demonstrate that the quantity of bonding material indicated in the core manufacturer's application procedure (*see* 2.11.2) is sufficient to penetrate the full depth of the core between the blocks. It is recommended that grid scored panels using a carrier scrim cloth are adopted.

4.2.10 Where the edges of a panel are to be bevelled to single skin the rate of tapering is to be not greater than 30°. In areas where an insert (e.g. higher density foam or plywood) is to be used the rate of taper is not to be greater than 45°.

4.2.11 In all application procedures cured, excess bonding material is to be removed and the panel cleaned and primed prior to the lamination of the final sandwich skin.

4.3 Inserts

4.3.1 Backing or insert pads where fitted in way of the attachment of fittings are to be arranged so that the load can be satisfactorily transmitted into the surrounding structure. The contact area of these pads is to be suitably prepared and free from contamination.

4.3.2 Inserts in sandwich laminates are to be of a material capable of resisting crushing. Inserts are to be well bonded to the core material and to the laminate skins in strict accordance with the approved plans.

4.3.3 Where plywood inserts are to be used all edges are to be bevelled at an angle of 45°. A small gap is to be provided around each insert to ensure the passage of bonding paste during the vacuum bagging process.

4.4 Vacuum bagging

4.4.1 Where wet vacuum bagging is proposed (with or without a core), full details are to be submitted for consideration.

4.4.2 The Builder is to demonstrate by visual inspection that efficient core bonding can be obtained using the proposed dry vacuum bagging process.

4.4.3 The number, size and distribution of breather holes in panels of rigid core material is to be that recommended in the core manufacturer's application procedure, *see* 4.2.6. Typically, 3 mm diameter breather holes are to be provided at 50 mm centres.

4.4.4 The level of vacuum applied for initial consolidation and during the cure period is not to be higher than that recommended, by the relevant manufacturer of the materials being used, to avoid the possibility of evaporative boiling and excessive loss of monomer.

■ *Section 5*
Details and fastenings

5.1 General

5.1.1 This Section contains the general Rule requirements to be complied with for fibre reinforced plastic craft being built under survey. Where detailed requirements are not defined good boat building practices are to be applied. Where different details are to be applied, the Builder is required to provide evidence of satisfactory service experience or acceptable test data.

5.2 Alignment

5.2.1 Details of alignment and building tolerances are to be laid down in the Builder's production plan.

5.2.2 Where details of alignment and building tolerances are not included on the construction plans, or submitted separately for consideration with the plan submission, they may, subject to individual consideration, be agreed locally with the attending Surveyor.

5.2.3 Particular attention is to be given to the accurate alignment of the following:
(a) girder abutting single skin bulkhead;
(b) girder webs with tank sides;
(c) frames with beams;
(d) deck/bottom girders with bulkhead stiffeners;
(e) tank baffles with floors;
(f) longitudinals where broken at tank ends; and
(g) transom stiffeners with bottom/deck girders.

5.2.4 For larger craft the hull breakage sight-line is to be progressively monitored during the construction of the craft and is to form part of the quality control documentation. The production plan is to identify maximum breakage limits dependent upon the size of the craft.

5.2.5 The production plan is to identify allowable tolerances for the alignment of the primary structural components.

5.2.6 To ensure efficient load transmission intercostal, single skin bulkheads are to be aligned to within half the thickness of the thinner bulkhead. In the case of sandwich construction the tolerance requirements will be individually considered dependent upon the sandwich panel dimensions and the construction of the continuous member. In general, the webs of the intercostal sandwich panel member are to be aligned to within 5 mm. Where poor alignment is identified, additional boundary bonding reinforcements are to be applied as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.2.7 To ensure efficient transmission of shear loads, the alignment tolerance of intercostal 'top hat' stiffener webs is, in general, to be within half of the web thickness. Where poor alignment is identified, additional reinforcements are, in general, to be incorporated into the stiffener webs as agreed with the attending Surveyor. Such deviations and details of the remedial action taken are to be recorded in the Builder's quality control documentation.

5.3 Continuity

5.3.1 Continuity of all primary structural members is to be maintained, as required by the Rules, and abrupt changes of section are to be avoided. Both primary and secondary stiffening members are to be continuous unless otherwise agreed with LR.

5.3.2 Special consideration will be given to the intersection of longitudinal and transverse members. In general the ratio between the depths of the intersecting members is to be 2:1. The shallower member is to be continuous under the supporting members.

5.3.3 Alternative proposals to the requirements given in 5.3.2 will be subject to special consideration in conjunction with the submission of details for maintaining the continuity of reinforcements at intersections in both directions. Where stiffeners are of similar dimensions the primary member is to be continuous. In general the section modulus of the continuous material is to be maintained.

5.4 Openings

5.4.1 All openings are to have well rounded corners and are to be supported on all sides. Cut edges of openings are to be sealed to prevent the ingress of moisture.

5.4.2 All hatch openings are to be supported by a system of transverse and longitudinal stiffeners, the details of which are to be submitted for approval.

5.4.3 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

5.4.4 All deck openings are to have corner radii as specified in Ch 3,8.12.

5.4.5 For details of sealing the edges of openings and sandwich panels, *see* 5.10.

5.5 Through bolting and bolted connections

5.5.1 The details of all through bolted structural connections are to be indicated on the relevant construction plans submitted for approval. The design of the joint is to be suitable for its intended purpose with a sufficient number of bolts to satisfactorily close the joint.

5.5.2 Tank tops may be bolted down provided the bolt spacing does not exceed $8d_b$, where d_b is the bolt diameter. A joint, seal or stop water is to be fitted, as necessary, to meet the required integrity.

5.5.3 In general, large headed bolts or large diameter thick washers are to be used to prevent localised crushing damage during tightening.

5.5.4 Where mechanical fastenings are used, the torque is to be indicated on the plans submitted for approval.

5.5.5 Bolting arrangements are, in general, to be in accordance with Ch 2,5.5, 5.6, 5.7 and 5.8. In FRP sandwich construction, inserts of a material capable of resisting crushing are to be fitted in accordance with 4.3.

5.5.6 The diameter of a fastening is not to be less than the thickness of the thinner component being fastened, with a minimum diameter of 6 mm, excepting window frames where the minimum diameter may be 5 mm.

5.5.7 Bolted connections are, in general, to be bonded along all mating surfaces using an accepted structural adhesive, applied in accordance with the manufacturer's requirements. Where connections rely solely on the shear resistance of the connecting bolts the spacing is not to exceed $3d_b$, where d_b is the diameter of the bolt. In areas where subsequent access will either be limited or not possible, self locking nuts are to be provided.

5.5.8 In general, all structural, bolted connections are to use reeled lines of bolts in accordance with the requirements given in Table 2.5.1.

Table 2.5.1 Bolt pitch requirements in bonded and bolted connections

Location	Pitch
Watertight connections – below static load waterline	 $10d_b$
Connections in hull above static load waterline to deck	$15d_b$
Hull to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	 $20d_b$ $20d_b$
Connections in deckhouses	$20d_b$
Deckhouse to deck connections – bonded with structural adhesive – bolted with mastic sealant (*see* Note 2)	 $20d_b$ $20d_b$
Minimum distance between reeled lines of bolts	$3d_b$
Minimum distance from centreline of line of bolts to free edge	$2d_b$

NOTES
1. d_b is the diameter of the bolt.
2. Internal boundary sealing angle to be provided.

5.5.9 All structural, single line, bolted connections without adhesive bondings are to be in accordance with the requirements given in Table 4.1.1 in Pt 3, Ch 4.

5.5.10 Care is to be taken to avoid distortion of the frame when window frames are bolted into the structure of the craft. Where necessary, uneven surfaces are to be locally built up to the satisfaction of the attending Surveyor.

5.5.11 Where a restricted service notation of G1 or G2 is applicable the requirements given in this Section will be specially considered dependent upon the sea states for which the craft is designed.

5.5.12 Bolt holes are to be drilled, without undue pressure at break through, having a diametric tolerance of two per cent of the bolt diameter. Where bolted connections are to be made watertight the hole is to be sealed with resin and allowed to cure before the bolt is inserted.

5.5.13 In areas of high stress or where unusual bolting configurations are proposed, testing on the basis of equivalence with the above Rules may be required.

5.6 Through hull fittings

5.6.1 Where fittings penetrate the hull envelope, care is to be taken to seal the hull laminate with resin or other suitable compound, *see* 5.10.

5.6.2 The areas in way of penetrations for fittings in sandwich construction are, in general, to comply with the requirements of 4.3. Where the requirements cannot be complied with, the core is to be replaced locally with a solid core or very high density foam core with compressive properties commensurate with the loads imposed by the securing arrangements, *see* 5.8.2. The exposed edges of such openings are to be sealed watertight, *see* Ch 3,3.10.

5.6.3 All bolted fittings are to be bedded down using a suitable mastic, details of which are to be indicated on the submitted plans.

5.7 Backing bars and tapping plates

5.7.1 The requirements for backing plates and bars will be individually considered, on the basis of the loading imposed, details of which are to be indicated on the submitted plans.

5.7.2 Metallic plates and bars are to comply with the requirements of 2.1.2 (such as suitable marine grades of stainless steel or aluminium alloys).

5.7.3 Tapping plates may be encapsulated within the laminate, laminated to or bolted to the structure, *see also* 2.15.1. Where tapping plate edges or corners are likely to give rise to hard spots or stress concentrations the edges are to be suitably rounded.

5.7.4 Where tapping plates are placed on foam cores the plate is to be mounted on a suitable foundation to prevent the movement of the tapping plate during drilling operations.

5.7.5 Direct calculations regarding the scantlings of tapping plates are to be provided at the plan appraisal stage.

5.8 Fastenings

5.8.1 All fastenings are to be of a suitable marine grade. Sizes and specifications are to be indicated on the submitted plans.

5.8.2 In areas where localised crushing of a sandwich core is likely to occur, large diameter washers, compression tubes or inserts or a combination of these are to be adopted.

5.9 Secondary bonding and peel ply

5.9.1 Laminating is to proceed as a continuous process, as far as practicable, with the minimum of delay between successive plies. Where a secondary bond is to be made it is to be carried out in accordance with the resin manufacturer's recommendation, details of which are to be incorporated in the Builder's quality control documentation. This will, in general, take the form of the area being lightly abraded and wiped with a suitable solvent, which is to be allowed to dry prior to laminating.

5.9.2 Where other than epoxy resins are being used, the first reinforcement is to be of the chopped strand mat type.

5.9.3 Consideration should be given, especially in highly stressed areas, to the application of peel ply materials to obviate contamination of the exposed surface, and thereby reducing the abrading required to obtain a good secondary bond.

5.10 Exposed edges

5.10.1 The exposed edges of all openings cut in single skin laminate panels are to be suitably sealed. Where such edges are in wet spaces or under water the edges of such openings are to have rounded edges and are to be sealed by two plies of 450 g/m^2 chopped strand mat (or equivalent) reinforcements, *see also* Ch 3,3.10.

5.10.2 Exposed edges of openings cut in sandwich panels are to be suitably sealed, *see* 5.6.2. The cut edges are, in general, to be sealed with a weight of reinforcement not less than that required for the outer skin of the sandwich. Where other than an epoxy resin system is used the first layer of such reinforcement is to be chopped strand mat with a weight not exceeding 450 g/m^2, *see also* Ch 3,3.10.

5.11 Joints

5.11.1 The details of all joints, the proposed jointing procedure and information regarding tolerancing are to be indicated on the submitted plans.

5.11.2 Joints may be bolted or adhesively bonded, or both. Where joints are bolted, full details of the bolt material, the proposed number and spacing are to be provided. Bolts are to be manufactured from a non-corrosive material or protected against corrosion.

5.12 Local reinforcement

5.12.1 Areas subject to local loads or increased stress are to be suitably reinforced, details of which are to be indicated on the submitted plans, *see* Ch 3,3.14.

5.12.2 The design of the structure, in way of the attachment of fittings or equipment in sandwich structures, is to be such that the induced loads can be transmitted into the surrounding structure by bending as opposed to shear. The areas are, in general, to take the form of suitably reinforced single skin areas, *see* Ch 3,3.14, with the additional layers of reinforcement staggered out onto the surrounding inner and outer skins as indicated in Fig. 3.3.1.

5.13 Hull to deck connections

5.13.1 Details of the hull to deck connection, the method of bonding and the tolerances are to be indicated on the submitted plans.

5.13.2 Hull to deck connections should, in general, be bolted and over-bonded. A suitable mastic or sealing compound is to be incorporated within the joint.

5.13.3 The bolting details should be reeled lines of bolts pitched as specified in Table 2.5.1. Suitable large diameter thick washers should be used under both the head and the nut.

5.13.4 Where a mastic is not used, sealing plies are to be applied on the inside of the hull.

5.13.5 The weight of the over-bonding reinforcement is, in general, not to be taken as less than equivalent to the lighter of the component members being connected, and in no case less than equivalent to three plies of 600 g/m^2 chopped strand mat.

5.13.6 Substantial beam knees are to be provided to maintain structural continuity between the transverse deck and hull stiffening.

5.13.7 The watertight integrity, continuity and strength of the connection is not to be impaired by the attachment of the hull fender.

5.13.8 For guidance details of scantlings required to resist impact loads at deck edge connections, *see* Ch 3,4.19 for side shell in way of fendering and Ch 3,3.6 for sheerstrakes.

5.14 Exhaust systems

5.14.1 Exhaust systems, manufactured from FRP, are to be of the water injected type with a normal operating temperature of 60° to 70°C and a maximum operating temperature of 120°C.

5.14.2 Exhaust pipes, silencers and water separators should be of a Type Approved design, installed strictly in accordance with the manufacturer's requirements.

5.14.3 Where a Type Approved system is not used, the arrangement will be considered on an individual basis. Resins used in the manufacture of exhaust systems are to be of a type approved by LR and are to have good heat and chemical resistance properties with a high deflection temperature under load. A vinylester resin should be used, but a fire retardant polyester resin, having a high heat distortion temperature, will be considered. Test samples may be required dependent upon the proposed arrangement, temperatures and materials.

5.14.4 It is recommended that pigments and additives are not used unless it can be demonstrated that the mechanical properties of the resin system remain unaffected. Resins used are not to show any embrittlement with age.

5.14.5 Special consideration is to be given to post curing of such systems to obtain optimal characteristics.

5.14.6 Due to the weight of water contained within the system, exhaust pipes and fittings are to be efficiently supported.

5.14.7 Exhaust boxes are to be lined with a minimum of two plies of 600 g/m^2 chopped strand mat (or equivalent) using a suitable fire retardant/high temperature resin.

5.14.8 For engineering aspects of exhaust systems reference is to be made to Pt 10, Ch 1,8.6.

5.14.9 National Authority requirements take precedence over the requirements given in this Section.

5.15 Ballast

5.15.1 The provision of permanent ballast is not to adversely affect the surrounding structure.

5.15.2 Where a resin compound is to be poured into a void space, care is to be taken to minimise the generation of heat that may affect the mechanical and weathering characteristics of the structural laminate.

5.15.3 Details of all ballast materials and the proposed method of installation are to be indicated on the submitted plans.

5.16 Limber holes

5.16.1 Provision is to be made to drain areas likely to accumulate liquids, details of which are to be indicated on the submitted plans.

5.16.2 The size, shape and position of limber holes are not to affect the structural strength of the stiffening members in which they are fitted. Limber holes are, in general, to be positioned at the quarter span of the stiffener.

5.17 Integral tanks (requirements for coatings)

5.17.1 The surfaces of integral tanks are to be provided with a barrier to reduce the ingress of liquid. The details of the proposed system are to be indicated on the submitted plans.

5.17.2 Fresh water tanks are to be coated with a non-toxic and non-tainting coat of resin that is recommended by the resin manufacturer for potable water tanks.

5.17.3 The design and arrangement of oil fuel tanks is to be such that there is no exposed horizontal section at the bottom that could be exposed to a fire. Other fire protection arrangements for oil fuel tanks will be specially considered. For details of fire protection requirements, *see* Part 17.

5.17.4 Where plywood bulkheads form part of a tank boundary, the surface is to be completely protected against the ingress of moisture with a minimum of 4 mm thickness of laminate to provide an effective fluid barrier, regardless of resin and reinforcement type used.

5.17.5 Where outfit items are to be laminated to the tank surface, the heavy coating of resin is to be applied afterwards and the laminated brackets sealed to prevent the ingress of moisture.

5.17.6 The scantlings of integral oil fuel and water tanks are to be in accordance with Ch 3,7. Details regarding sub-division of integral tanks are given in Ch 3,7.11.1.

5.17.7 Integral tanks are to be tested in accordance with Ch 3,7.17.

5.18 Reserve buoyancy

5.18.1 Details of materials to be used and the method of installation of reserve buoyancy are to be indicated on the submitted plans.

5.18.2 Where necessary, buoyancy materials are to be over-laminated *in situ* to prevent the ingress of moisture.

5.19 Shear ties (stiffeners)

5.19.1 Where the total web depth to thickness ratio requirement in Ch 3,1.16 for buckling of stiffener webs is not complied with, cross linking of the stiffener webs at the Rule depth to thickness ratio is to be provided by the use of shear ties, as indicated in Fig. 2.5.1.

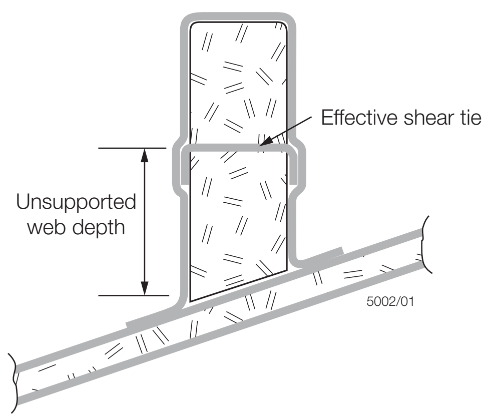


Fig. 2.5.1 Arrangement of shear ties (stiffeners)

5.19.2 Alternative arrangements will be subject to individual consideration in conjunction with submitted direct calculations.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 The scantlings of motor and sailing, mono-hull craft of conventional form and proportions are to be determined from the formulae contained within this Chapter.

1.2.2 The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests, or the mean values minus twice times the standard deviation for the five samples, whichever is the lesser. All test pieces are to be representative of the product to be manufactured and details submitted for consideration.

1.2.3 In the absence of suitable test data, the mechanical properties of the materials is to be estimated from the appropriate procedures and formulae contained within this Part. The acceptable design values for glass reinforced polyester resin laminates are, in general, not to be taken greater than those determined from Tables 3.1.1 to 3.1.3. Additional information on the application of the various formulae is given in Lloyd's Register's (hereinafter referred to as 'LR') *Guidance Notes for Calculation Procedures for Composite Construction*.

Table 3.1.1 Mechanical properties for chopped strand mat (CSM) glass reinforced polyester resin laminates

Mechanical property	N/mm^2
Ultimate tensile strength	$200f_c + 25$
Tensile modulus	$(15f_c + 2) \times 10^3$
Ultimate compressive strength	$150f_c + 72$
Compressive modulus	$(40f_c – 6) \times 10^3$
Ultimate shear strength	$80f_c + 38$
Shear modulus	$(1,7f_c + 2,24) \times 10^3$
Ultimate flexural strength	$502f_c^2 + 106,8$
Flexural modulus	$(33,4f_c^2 + 2,2) \times 10^3$
NOTE f_c is as defined in 1.5.1.	

Table 3.1.2 Mechanical properties for woven roving (WR) and cross plied (CP) glass reinforced polyester resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Ultimate tensile strength	$400f_c – 10$
Tensile modulus	$(30f_c – 0,5) \times 10^3$
Ultimate compressive strength	$150f_c + 72$
Compressive modulus	$(40f_c – 6) \times 10^3$
Ultimate shear strength	$80f_c + 38$
Shear modulus	$(1,7f_c + 2,24) \times 10^3$
Ultimate flexural strength	$502f_c^2 + 106,8$
Flexural modulus	$(33,4f_c^2 + 2,2) \times 10^3$
NOTE f_c is as defined in 1.5.1.	

1.2.4 In the absence of suitable test data, the mechanical properties of aramid and carbon reinforced epoxy resin laminates are, in general, not to be taken greater than those determined from Tables 3.1.4 to 3.1.7.

1.2.5 The various formulae referred to in 1.2.3 and 1.2.4 require that sufficient input data be available which relates to each of the proposed materials. The designers and/or Builders are to, in general, agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

1.2.6 Typical acceptable values for the various fibre properties of materials commonly in use are given in Table 3.1.8.

Table 3.1.3 Mechanical properties for uni-directional glass reinforced polyester resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(50{,}5f_c - 6{,}87) \times 10^3$
Transverse elastic modulus	$(19{,}6f_c^2 - 15{,}7f_c + 6{,}6) \times 10^3$
In-plane shear modulus	$(7{,}3f_c^2 - 5{,}9f_c + 2{,}4) \times 10^3$
Longitudinal tensile strength	$656f_c - 89{,}3$
Longitudinal compressive strength	$530f_c - 72{,}1$
Transverse tensile strength	$68{,}4f_c^2 - 55f_c + 23$
Transverse compressive strength	$196f_c^2 - 157f_c + 65{,}6$
In-plane shear strength	$73{,}4f_c^2 - 59{,}2f_c + 24{,}5$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0{,}4 < f_c < 0{,}7$. Laminates with fibre contents outside range of applicability will be specially considered.

Table 3.1.4 Mechanical properties for uni-directional aramid reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(91{,}2f_c + 1{,}1) \times 10^3$
Transverse elastic modulus	$(1{,}5f_c + 2{,}4) \times 10^3$
In-plane shear modulus	$(8{,}6f_c^2 - 6{,}1f_c + 2{,}6) \times 10^3$
Longitudinal tensile strength	$1186f_c + 14{,}3$
Longitudinal compressive strength	$319f_c + 3{,}8$
Transverse tensile strength	$7{,}5f_c + 12{,}1$
Transverse compressive strength	$22{,}4f_c + 36{,}4$
In-plane shear strength	$129f_c^2 - 92f_c + 38{,}4$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0{,}25 < f_c < 0{,}55$. Laminates with fibre contents outside range of applicability will be specially considered.

Table 3.1.5 Mechanical properties for woven roving (WR) and cross-plied (CP) aramid reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Elastic modulus	$(46{,}4\ f_c + 1{,}76) \times 10^3$
In-plane shear modulus	$(8{,}6\ f_c^2 - 6{,}1\ f_c + 2{,}6) \times 10^3$
Tensile strength	$596\ f_c + 13{,}2$
Compressive strength	$171\ f_c + 20{,}1$
In-plane shear strength	$129\ f_c^2 - 92\ f_c + 38{,}4$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0{,}25 < f_c < 0{,}55$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.6 Mechanical properties for uni-directional carbon reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Longitudinal elastic modulus	$(153f_c - 9{,}80) \times 10^3$
Transverse elastic modulus	$(5{,}8f_c^2 - 2{,}6f_c + 3{,}5) \times 10^3$
In-plane shear modulus	$(8{,}9f_c^2 - 6{,}6f_c + 2{,}7) \times 10^3$
Longitudinal tensile strength	$1377f_c - 88{,}2$
Longitudinal compressive strength	$842f_c - 53{,}9$
Transverse tensile strength	$21{,}7f_c + 7{,}5$
Transverse compressive strength	$65{,}2f_c + 22{,}4$
In-plane shear strength	$132f_c^2 - 99{,}5f_c + 40$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0{,}3 < f_c < 0{,}6$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.7 Mechanical properties for woven roving (WR) and cross-plied (CP) carbon reinforced epoxy resin laminates at 0/90° degree orientation

Mechanical property	N/mm^2
Elastic modulus	$(78,7f_c - 4,15) \times 10^3$
In-plane shear modulus	$(8,8f_c^2 - 6,6f_c + 2,7) \times 10^3$
Tensile strength	$690f_c - 35,3$
Compressive strength	$453f_c - 15,7$
In-plane shear strength	$132f_c^2 - 99,5f_c + 40$

NOTES
1. f_c is as defined in 1.5.1.
2. Range of applicability: $0,3 < f_c < 0,6$. Laminates with fibre content outside range of applicability will be specially considered.

Table 3.1.8 Typical minimum fibre properties

	Specific gravity ζ_F	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio μ_F
E glass	2,56	69000	28000	0,22
S glass	2,49	69000	— *see* Note 3	0,20
R glass	2,58	— *see* Note 3	— *see* Note 3	— *see* Note 3
Aramid	1,45	124000	2800	0,34
LM graphite *see* Note 1	1,80	230000	— *see* Note 3	— *see* Note 3
IM graphite *see* Note 1	1,80	270000	— *see* Note 3	— *see* Note 3
HM graphite *see* Note 1	1,8	300000	— *see* Note 3	— *see* Note 3
IM graphite *see* Note 2	1,9	160000	— *see* Note 3	— *see* Note 3
HM graphite *see* Note 2	2,0	380000	— *see* Note 3	— *see* Note 3
VHM graphite *see* Note 2	2,15	725000	— *see* Note 3	— *see* Note 3

NOTES
1. Polyacryonitrile type.
2. Mesophase pitch precursor type.
3. Actual values to be obtained from the material manufacturer and are to be agreed with LR prior to use.

1.2.7 Typical acceptable values for the various resin properties of materials commonly in use are given in Table 3.1.9.

1.3 Direct calculations

1.3.1 The scantlings are to be determined by direct calculation where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots.

1.3.2 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Ch 2,3 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.5 Symbols and definitions

1.5.1 The symbols used in this Chapter, unless specified otherwise, are defined as follows:

b = unsupported panel breadth, in mm
b_i = breadth of individual ply, *i*, in mm
e_f = flexural strain of plate laminate
B = moulded breadth of the craft, in metres
E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2
E_{cp} = compressive modulus of plate laminate, in N/mm^2
E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis
E_F = tensile modulus of the fibres, in N/mm^2
E_R = tensile modulus of the resin, in N/mm^2
E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2
E_{cps} = compressive modulus of the sandwich skin plate laminate as determined from 1.13.5, in N/mm^2
E_{tps} = tensile modulus of the sandwich skin plate laminate as determined from 1.13.4, in N/mm^2
E_{fp} = flexural modulus of plate laminate, in N/mm^2
E_{tp} = tensile modulus of the plate laminate, in N/mm^2
f_c = the fibre content, by weight, within the laminate
f_{ci} = fibre content, by weight, of individual ply, *i*
G = shear modulus of sandwich core material, in N/mm^2
I_i = second moment of area for a 1 cm length of the cross section of individual ply, *i*, in cm^4
I_P = second moment of area for a 1 cm length of the cross section of plate laminate, in cm^4
k_A = $85/\sigma_u$
k_s = sandwich laminate aspect ratio correction factor, as defined in 1.13.9
L_R = Rule length of craft, in metres
M = bending moment, as appropriate, in Nm
l_e = effective span length of stiffener, in metres
σ_u = ultimate tensile strength of the plate laminate, in N/mm^2

Table 3.1.9 Typical minimum resin properties

	Type	Specific gravity ζ_R	Tensile modulus N/mm^2	Shear modulus N/mm^2	Poisson's ratio ν_R
Polyester	Thermosetting	1,20	3400	1300	0,36
Vinylester	Thermosetting	1,44	3500	— *see* Note	— *see* Note
Epoxy	Thermosetting	1,38	3500	— *see* Note	0,39
Phenolic	Thermosetting	1,30	1500~2500 *see* Note	— *see* Note	— *see* Note
NOTE Actual value to be obtained from the material manufacturer and is to be agreed with LR prior to use.					

p = design pressure in kN/m^2, as calculated in Part 5 for the appropriate item
s = stiffener spacing, in mm
t_c = core thickness, in mm
t_i = thickness of individual ply, i, in mm
t_p = thickness of plate laminate, in mm
t_s = mean skin thickness, in mm
ν_F = Poisson's ratio for the fibre
ν_R = Poisson's ratio for the resin
V_{Fi} = volume fraction of fibres of individual ply, i
W_{Fi} = weight fraction of the fibres of individual ply, i
m_{Fi} = mass of reinforcement in individual ply, i, in g/m^2
x_i = distance to the centre of individual ply, i, from the plate or sandwich laminate surface, in mm
x_L = distance of the neutral axis from the surface of the plate or sandwich laminate, in mm
x_S = the distance of the neutral axis, from the outer surface of the plate or sandwich laminate
y_i = distance from the neutral axis to the outer extremity of an individual ply, i, in mm
σ_{ci} = maximum compressive stress within ply, i, in N/mm^2
σ_{ti} = maximum tensile stress within ply, i, in N/mm^2
ζ_{Fi} = specific gravity of reinforcement in individual ply, i
ζ_{Ri} = specific gravity of resin in individual ply, i.

1.5.2 The side shell is defined as the portion of the hull between the bottom shell and the deck at side.

1.6 Material properties

1.6.1 The nominal thickness of an individual ply, t_i, may be determined from:

$$t_i = \frac{m_{Fi}\left[\dfrac{\zeta_{Fi}}{f_{ci}} - (\zeta_{Fi} - \zeta_{Ri})\right]}{1000\zeta_{Fi}\,\zeta_{Ri}} \text{ mm}$$

where
f_{ci}, t_i, m_{Fi}, ζ_{Fi} and ζ_{Ri} are as defined in 1.5.1.

1.7 Effective width of attached plating

1.7.1 The geometric properties of stiffening sections are to be calculated in accordance with 1.15 using an effective width, $2b_1$, of attached load bearing plating determined as follows:

(a) Single skin construction:
$b_1 = 0{,}5b_w + 10t_{ap}$

(b) Sandwich skin construction:
Generally:
$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner})$
Where a plywood core is used:
$b_1 = 0{,}5b_w + 10(t_{outer} + t_{inner} + 0{,}5t_{ply})$
where
b_1 = effective width of attached load bearing plating, in mm, and is not to be taken as greater than one half the spacing between the centres of adjacent stiffeners
b_w = base width of the stiffener section, in mm
t_{ap} = thickness, or mean thickness of attached plate laminate, in mm
t_{inner} = thickness, or mean thickness of inner skin laminate, in mm
t_{outer} = thickness, or mean thickness of outer skin laminate, in mm
t_{ply} = thickness of plywood core, in mm.

1.7.2 The geometric properties of primary support members (i.e. girders, stringers, web frames, etc.) are to be calculated in accordance with 1.15 using an effective area of attached load bearing plate laminate of nominal thickness, t mm, and of width equal to one-half the sum of spacings between parallel adjacent members or equivalent support.

1.8 Glass fibre and advanced fibre composites

1.8.1 Strength calculations for all advanced fibre composites are to be based on the results of testing of truly representative sections of the proposed design. In general the sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays.

1.8.2 Mechanical testing is, in general, to be based upon the requirements of Ch 14,3 of the Rules for Materials.

1.8.3 Where test data is not available for standard glass fibre laminates, the following theoretical approach is to be used to estimate the tensile modulus and the shear modulus of a laminate:

The tensile modulus of a uni-directional reinforcement at angle θ to the axis of the fibres is to be determined from:

$$E_{\theta i} = \frac{E_{0i}}{\cos^4\theta_i + \dfrac{E_{0i}}{E_{90i}}\sin^4\theta_i + \dfrac{1}{4}\left(\dfrac{E_{0i}}{G_{0/90i}} - 2\nu_{0/90i}\right)\sin^2 2\theta_i}\ \text{N/mm}^2$$

where

θ_i = angle of orientation of the fibre relative to the warp direction, and is not to be taken as less than seven degrees to allow for misalignment

E_{0i}, the longitudinal tensile modulus of individual ply, *i*, for an unfilled resin system is determined from:

$$E_{0i} = E_F V_F + E_R (1 - V_F)\ \text{N/mm}^2$$

E_F, V_F and E_R are as defined in 1.5.1

V_F, the volume fraction of the fibres of individual ply, *i*, is determined from:

$$V_F = \frac{W_F \zeta_R}{W_F \zeta_R - W_F \zeta_F + \zeta_F}$$

W_F, ζ_F and ζ_R are as indicated in 1.5.1

E_{90i}, the transverse tensile modulus of individual ply, *i*, is determined from:

$$E_{90i} = \frac{E_F E_R}{E_R V_F + E_F - E_F V_F}\ \text{N/mm}^2$$

E_F, E_R and V_F are as indicated in 1.5.1.

$G_{0/90i}$, the shear modulus of individual ply, *i*,is determined from:

$$G_{0/90i} = G_R \left\{ \frac{\dfrac{G_F}{G_R}(1 + V_F) + (1 - V_F)}{\dfrac{G_F}{G_R}(1 - V_F) + (1 + V_F)} \right\}\ \text{N/mm}^2$$

Where the shear modulus of the resin, G_R is determined from:

$$G_R = \frac{E_R}{2(1 + \nu_R)}\ \text{N/mm}^2$$

Where the shear modulus of the fibre, G_F is determined from:

$$G_F = \frac{E_F}{2(1 + \nu_F)}\ \text{N/mm}^2$$

E_F, E_R, ν_R and ν_F are as indicated in 1.5.1.

The longitudinal Poisson's ratio, $\nu_{0/90}$, of individual ply, *i*, is determined as follows:

$$\nu_{0/90} = V_F(\nu_F - \nu_R) + \nu_R$$

V_F, ν_F and ν_R are as indicated in 1.5.1.

1.8.4 Where specific test data is not available for glass fibre reinforced polyester laminates, the mechanical properties for design are to be the values determined from the formulae given in Tables 3.1.1 and 3.1.2.

1.9 Plate and sandwich laminates

1.9.1 Unless otherwise specified in this Part, the bending moments, M_b and M_c, to be applied to a 1 cm length of panel, for both plate and sandwich laminates, subjected to lateral pressure are to be determined from:

(a) Bending moment at panel boundary and under base of stiffener, M_b:

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5}\ \text{Nm}$$

(b) Bending moment at centre of panel, M_c:

$$M_c = \frac{(1{,}5 - k)\,p\,b^2}{12} \times 10^{-5}\ \text{Nm}$$

where

$$k = \frac{\gamma^3 + 1}{\gamma + 1}$$

$$\gamma = \frac{b_w}{b}$$

b_w < b and is as defined below, *see* Fig. 3.1.1:

b = unsupported panel breadth, in mm

b_w = base width of stiffener, in mm

γ = ratio of base width of stiffener to panel breadth

k = bending moment influence coefficient

l_p = panel length, in mm

p = design pressure head as required by Part 5, for the element of plate laminate under consideration, in kN/m^2.

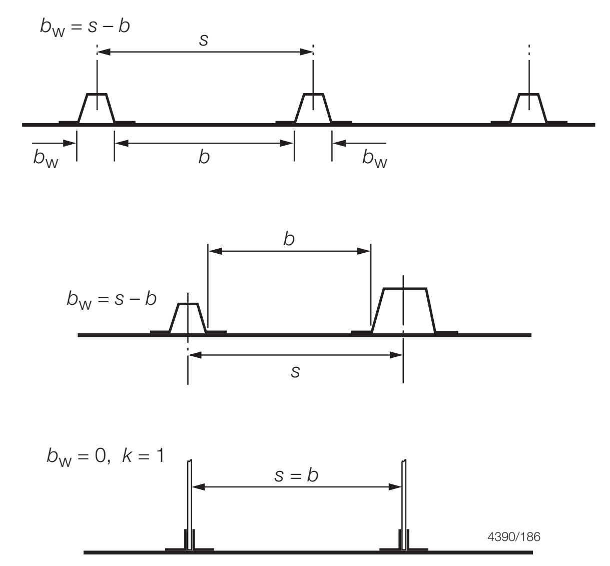


Fig. 3.1.1 Panel dimensions

1.10 Aspect ratio correction

1.10.1 The Rule bending moments, M_b and M_c, to be applied to plate laminates as determined by 1.9.1, may be reduced when the panel aspect ratio is taken into consideration. For panels with aspect ratio less than two the following factor, K_{AR}, may be applied:

$$K_{AR} = 0{,}56 + 0{,}63\ \ln(A_R) \geq 0{,}56$$

where

A_R = panel aspect ratio
= panel length/panel breadth

1.11 Convex curvature

1.11.1 The Rule bending moments, M_b and M_c, as determined by 1.9.1, may be reduced where significant curvature exists between the support members. For such panels the following factor, K_c, may be applied:

$$K_c = 1 - 1{,}76 \frac{h}{s} \geq 0{,}56$$

where
h = the distance, in mm, measured perpendicularly from the chord length s (i.e. spacing) to the highest point of the curved plating arc between the two supports, *see* Fig. 3.1.2.

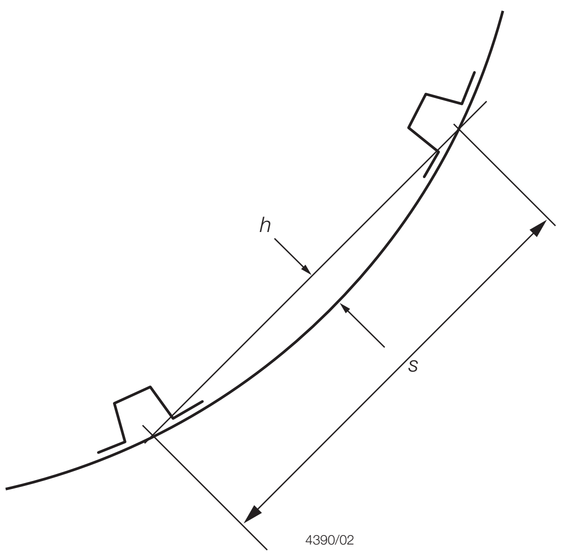


Fig. 3.1.2 Convex curvature

1.12 Determination of properties and stresses for single skin plate laminates

1.12.1 An estimate of the thickness of single skin plating required to carry the bending moment given in 1.9.1, is to be determined from:

$$t = 0{,}146 b \sqrt[3]{\frac{p}{E_{tp}}} \text{ mm}$$

where
b, p and E_{tp} are as defined in 1.5.1.

1.12.2 The distance of the neutral axis, x_L, from the surface of the plate laminate is to be determined from the following:

$$x_L = \frac{\Sigma (E_i t_i x_i)}{\Sigma (E_i t_i)} \text{ mm}$$

where
E_i, t_i and x_i are as defined in 1.5.1.

1.12.3 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti}\, y_i\, M}{\Sigma (E_i I_i)} \text{ N/mm}^2$$

where
σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.4 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, *i*, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci}\, y_i\, M}{\Sigma (E_i I_i)} \text{ N/mm}^2$$

where
σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

1.12.5 The effective flexural modulus of elasticity in bending, E_{fp}, for the plate laminate is to be determined from:

$$E_{fp} = \frac{\Sigma (E_i I_i)}{I_p} \text{ N/mm}^2$$

where
E_{ti}, I_i and I_P are as defined in 1.5.1.

1.12.6 The apparent flexural strength, sf, of a plate laminate is to be determined from:

$$\sigma_f = E_{fp}\, e_f \text{ N/mm}^2$$

where
E_{fp} and e_f are as defined in 1.5.1.

1.13 Mechanical properties sandwich laminates

1.13.1 For the application of the various formulae relating to the use of sandwich construction, the following assumptions have been made:

(a) the sandwich skins carry the majority of the bending load,
(b) the core carries the majority of the shear load,
(c) the initial estimate of the skin thickness from 1.13.2 is based upon the limiting condition for thin skin theory:

$$\frac{\text{Core thickness}}{\text{Mean facing thickness}} \geq 5{,}77$$

(d) the sandwich skins are of approximately equal thickness (i.e. the panel is of balanced or approximately balanced construction), with the thickness of the outer sandwich facing not greater than:
t_{OUTER} = 1,33 t_{INNER} (excluding gel coat and non-structural materials).

1.13.2 An estimate of the thicknesses of the sandwich skins and core required to carry the Rule bending moment may be determined from the following formula. The subsequent design is then to be tested against the other criteria required by the Rules.

$$t_s = \phi_1\, k_S\, b \sqrt[3]{\frac{p}{E_{tps}}} \text{ mm}$$

where

ϕ_1 = 0,0214 for inner skins
= 0,0286 for outer skins
= 0,1440 for core thickness

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.3 Where it is proposed to use a thicker core than assumed in 1.13.2, the required skin thickness, t_s, is to be calculated from:

$$t_s = \frac{\phi^2 \, p \, b^3}{E_{tps} \, t_c^2} \times 10^{-3} \text{ mm}$$

where

ϕ_2 = 0,446 for inner skins
= 0,594 for outer skins

k_S, E_{tps}, b and p are as defined in 1.5.1.

1.13.4 The tensile modulus, E_{tp}, of a plate laminate which forms a skin of a sandwich laminate subject to tensile loading is to be determined from:

$$E_{tps} = \frac{\Sigma \, (E_{ti} \, t_i)}{\Sigma \, t_i} \text{ N/mm}^2$$

where

E_{tps}, E_{ti} and t_i are as defined in 1.5.1.

1.13.5 The compressive modulus, E_{cp}, of a plate laminate which forms a skin of a sandwich laminate subject to compressive loading is to be determined from:

$$E_{cps} = \frac{\Sigma \, (E_{ci} \, t_i)}{\Sigma \, t_i} \text{ N/mm}^2$$

where

E_{cps}, E_{ci} and t_i are as defined in 1.5.1.

1.13.6 The distance of the neutral axis, x_S, from the outer surface of the sandwich laminate is to be determined from:

$$x_S = \frac{\Sigma \, (E_i \, t_i \, x_i)}{\Sigma \, (E_{ti} \, t_i)} \text{ mm}$$

where

E_i, t_i and x_i are as defined in 1.5.1.

1.13.7 The resultant tensile stress, σ_{ti}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1 E_{ti} \, y_i \, M}{\Sigma \, (E_i \, I_i)} \text{ N/mm}^2$$

where

σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable tensile stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.8 The resultant compressive stress, σ_{ci}, at the extreme outer fibre of an individual ply, i, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci} \, y_i \, M}{\Sigma \, (E_i \, I_i)} \text{ N/mm}^2$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The allowable compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

1.13.9 The direct core shear stress, τ_c, at the edges of a sandwich panel subjected to lateral pressure is to be determined from:

$$\tau_c = \frac{p \, b \, k_S}{2(t_c + t_s)} \times 10^{-3} \text{ N/mm}^2$$

where

k_S = aspect ratio correction factor
= $0{,}32 \, A_R + 0{,}36$ for $A_R \leq 2$
= 1,0 for $A_R > 2$

A_R = panel length/panel breadth

t_c and t_s are as defined in 1.5.1.

The allowable shear stress limits against core shear failure indicated in Ch 7,3.5.1. are to be complied with. For the purposes of this comparison it is assumed that the stated shear properties of the proposed core material have been determined by use of the four point sandwich beam bending test ASTM C393 or equivalent.

1.13.10 Where the core shear stress, τ_c, determined from 1.13.9 is in excess of the limiting stress for a particular core material, the effective shear strength of the core material in the direction of the panel breadth, may be increased by the addition of shear ties. The effective shear strength, τ_{eff}, of the core material is to be determined from:

$$\tau_{eff} = \tau_c + \left(\frac{t_t}{s_t} \times \tau_t \right) \text{ N/mm}^2$$

where

τ_{eff} = effective shear strength of the core material, in N/mm²

τ_c = shear strength of basic core material, in N/mm²

t_t = thickness of shear tie material, in mm

τ_t = ultimate shear strength of the shear tie material, in N/mm²

s_t = spacing or mean spacing of the shear ties, in mm.

1.13.11 Where the Poisson's ratio, ν_f, for a particular facing laminate is known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be determined from:

$$\delta = \frac{p \, b^2}{8 t_c} \left(\frac{b^2 \, (1 - \nu_f^2)}{24 E_{ms} \, t_s \, t_c} + \frac{1}{G} \right) \times 10^{-3} \text{ mm}$$

where the mean skin modulus, E_{ms}, is given by:

$$E_{ms} = \frac{\Sigma \, (E_p \, t_s)}{\Sigma \, t_s} \text{ N/mm}^2$$

E_p is E_{tp} or E_{cp} whichever is the lesser.

where

ν_f, p, b, t_c, t_s, E_{tp}, E_{cp} and G are as defined in 1.5.1 and E_{ms} is the mean modulus of the total skin thicknesses.

1.13.12 Where the Poisson's Ratio, ν_f, for a particular facing laminate is not known, the deflection, δ, of a flat sandwich panel with all edges assumed to be fully fixed, and subjected to a uniform lateral pressure is to be estimated from:

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \times 10^{-3} \text{ mm}$$

where
δ, p, b, t_c, t_s, and G, are as defined in 1.5.1
E_{ms} is as defined in 1.13.11.

1.13.13 The deflection determined from 1.13.11 or 1.13.12, as appropriate, is not to exceed the limiting deflection for the structural element under consideration, as indicated in Table 7.2.1 in Chapter 7.

1.14 Stiffeners general

1.14.1 Unless otherwise specified elsewhere in this Part, the Rule bending moment, M_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$M_s = \phi_M\, s\, l_e^2\, p \quad \text{Nm}$$

where
ϕ_M = bending moment coefficient as given in Table 3.1.10.

1.14.2 Unless otherwise specified elsewhere in this Part, the Rule shear force, F_s, to be applied to all stiffening members subjected to uniform lateral pressure is to be determined from:

$$F_s = \phi_s\, p\, s\, l_e \quad \text{N}$$

where
ϕ_S = shear force coefficient as given in Table 3.1.10.

1.14.3 The shear stress, τ_S, in the webs of stiffening members of 'top-hat' type section is to be determined from:

$$\tau_S = \frac{F_S}{2t_w\, d_W} \quad \text{N/mm}^2$$

where
F_S = shear force applied to the stiffening member, in *N*, as detailed in 1.14.2
t_W = stiffening member web thickness, in mm
d_W = stiffening member web depth, in mm. (Account is to be taken of the increased effective depth of web where the webs are inclined)

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.4 The shear stress, τ_S, in the webs of stiffening members of inverted angle or 'T bar' type section is to be determined from:

$$\tau_S = \frac{F_S}{t_W\, d_W} \quad \text{N/mm}^2$$

where
F_S, t_W and d_W are as defined in 1.14.3.

The maximum allowable shear stress is not to exceed that determined from Table 7.3.1 in Chapter 7, for the stiffener member under consideration.

1.14.5 Unless otherwise specified elsewhere in this Part, the deflection, δ_S, of stiffening members, subjected to uniform lateral pressure is to be determined from:

$$\delta_S = \frac{\phi_\delta\, p\, s\, l_e^4}{(E\,I)_S} \times 10^5 \text{ mm}$$

where
$(E\,I)_S$ = total $E\,I$ for the stiffener section including an effective width of attached plating as indicated in 1.7.1, in Ncm^4/mm^2
ϕ_δ = deflection coefficient as defined in Table 3.1.10
s, l_e, E, I and p are as defined in 1.5.1.

1.14.6 The maximum allowable deflection is not, in general, to exceed that determined from Table 7.2.1 in Chapter 7 for the stiffener member under consideration.

1.15 Geometric properties stiffener sections

1.15.1 The effective geometric properties of the stiffener sections are to be calculated directly from the dimensions of the section and associated effective width of attached plating in accordance with 1.7. Where the mean line of the stiffener webs is not normal to the attached laminate, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plate laminate. Where plywood, solid timber, aluminium alloy, steel or other materials are integrated into a stiffening member, the effectiveness of the material is to be determined in accordance with 1.20.3. The stress in the individual material is to be limited to the allowable strain associated with the constituent material.

1.15.2 The distance of the neutral axis, x_S, from the outer surface of the plate laminate is to be determined from:

$$x_S = \frac{\Sigma\,(E_i\, t_i\, b_i\, x_i)}{\Sigma\,(E_i\, t_i\, b_i)} \quad \text{mm}$$

where
E_i, t_i, b_i and x_i are as defined in 1.5.1.

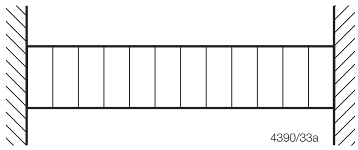
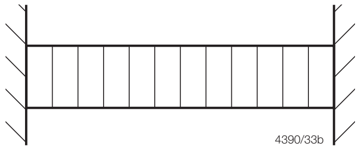
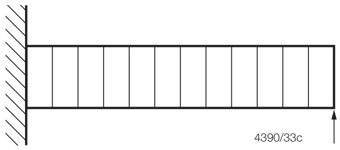
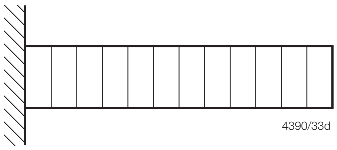
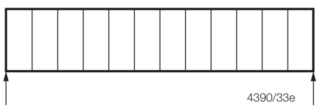
1.15.3 The resultant extreme fibre tensile stress for an individual ply, σ_{ti}, is to be determined from:

$$\sigma_{ti} = \frac{0{,}1E_{ti}\, y_i\, M}{\Sigma\,(EI)_S} \quad \text{N/mm}^2$$

where
σ_{ti}, E_{ti}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_S$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

Table 3.1.10 Shear force, bending moment and deflection coefficients

Load model	Position			Position	Shear force, ϕ_S	Bending moment, ϕ_M	Deflection, ϕ_δ	Application
	1	2	3					
(a)				1 2 3	1/2 — 1/2	1/12 1/24 1/12	— 1/384 —	Primary and other members where the end fixity is considered encastre
(b)				1 2 3	1/2 — 1/2	1/10 1/10 1/10	— 1/288 —	Local, secondary and other members where the end fixity is considered to be partial
(c)				1 2 3	5/8 — 3/8	1/8 9/128 —	— 1/185 —	Various
(d)				1 2 3	1 — —	1/2 — —	— — 1/8	Various
(e)				1 2 3	1/2 — 1/2	— 1/8 —	— 5/384 —	Hatch covers, glazing and other members where the ends are simply supported

1.15.4 The resultant extreme fibre compressive stress for an individual ply, σ_{ci}, is to be determined from:

$$\sigma_{ci} = \frac{0{,}1 E_{ci}\, y_i\, M}{\Sigma\,(EI)_s}$$

where

σ_{ci}, E_{ci}, y_i, M, E_i and I_i are as defined in 1.5.1.

The term $(EI)_s$ refers to the whole stiffener section, i.e. including the attached plating in accordance with 1.7. *See also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

1.16 Stiffener proportions

1.16.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with the requirements of this Section.

1.16.2 The thickness of the web for 'top-hat' type stiffeners, t_w, is to be not less than that required to satisfy the web shear from 1.14.3 and 1.14.4, and in no case is to be taken as less than that determined from the following formula:

$$t_w = \frac{0{,}025 d_w + 1{,}1}{1{,}3 f_w + 0{,}61} \text{ mm}$$

where

d_w = unsupported web depth, in mm

f_w = fibre content, by weight, of the web laminate.

1.16.3 The thickness of the web of an inverted angle or 'T' bar stiffener section is to be twice the web thickness determined from 1.16.2.

1.17 Determination of span points

1.17.1 The effective span, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined from:

(a) For secondary stiffening members of top-hat type section as shown in Fig. 3.1.3(a) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member is equal to the depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary stiffening members of top-hat type section as shown in Fig. 3.1.3(b) the span point is to be taken at the point where the depth of the end bracket, measured from the face of the primary stiffening member is equal to the half depth of the member. Where there is no end bracket, the span point is to be measured between primary member webs.

1.17.2 Where the stiffener member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

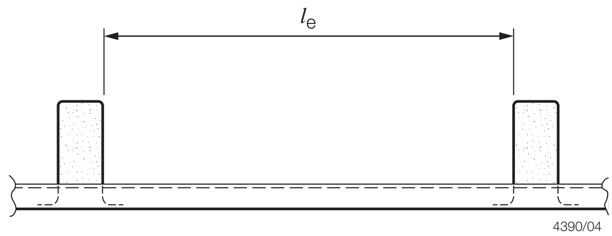


Fig. 3.1.3(a) Span points

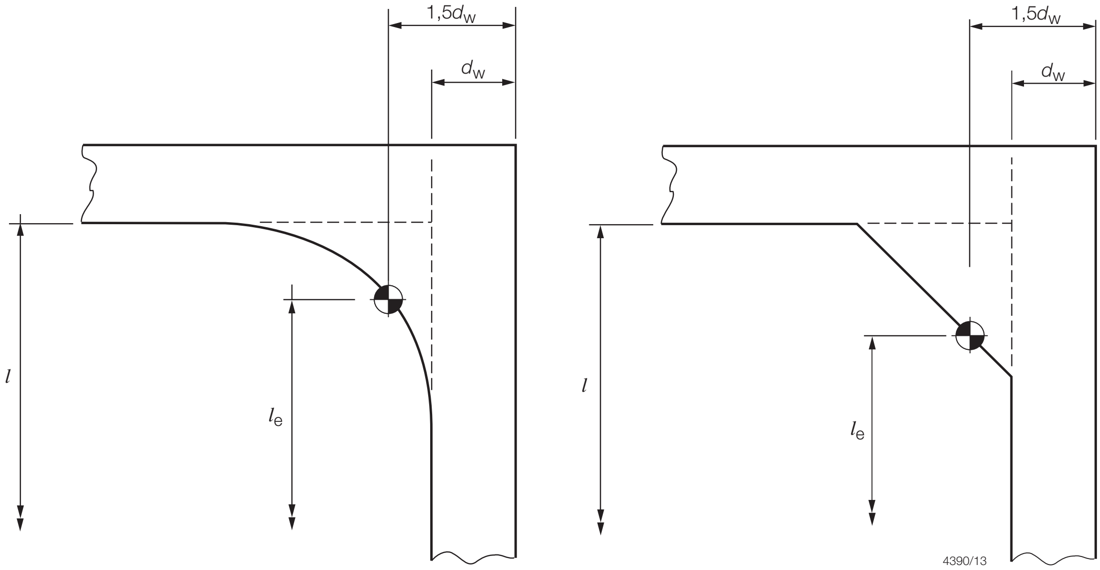


Fig. 3.1.3(b) Span points

1.17.3 Where the stiffening member is curved then the span is to be taken as the effective chord length.

1.17.4 Where there is a pronounced turn of bilge, chine or the structure is significantly pitched, the span is to be measured as in Fig. 3.1.3(c) to (f).

1.17.5 The determined effective span assumes that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, the span is to be determined excluding any effect from the end brackets.

1.18 Boundary bonding

1.18.1 The connection of the various laminates into assemblies and the connection of units to the main structure is generally to be made by means of single or double angles of the type shown in Fig. 3.1.4.

1.18.2 These matting-in angles are to be formed by layers of reinforcements, laid-up *in situ*, and normally secondary bonded to the structure before the laminates are advanced in cure. Where the laminating schedule is such that this cannot be achieved then suitable peel plies and secondary bonding techniques, as recommended by the resin manufacturer, *see* Ch 2,5.9, are to be arranged in way of the surfaces to be connected.

1.18.3 All surfaces to be bonded are to be clean and suitably prepared prior to the application of the bonding angles. Suitable fillets of compliant resin are to be arranged as shown in Figs. 3.1.5 and 3.1.6.

1.18.4 Where floors, bulkheads, tank boundaries, etc., are manufactured from plate laminate the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the lighter member being connected, or 900g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

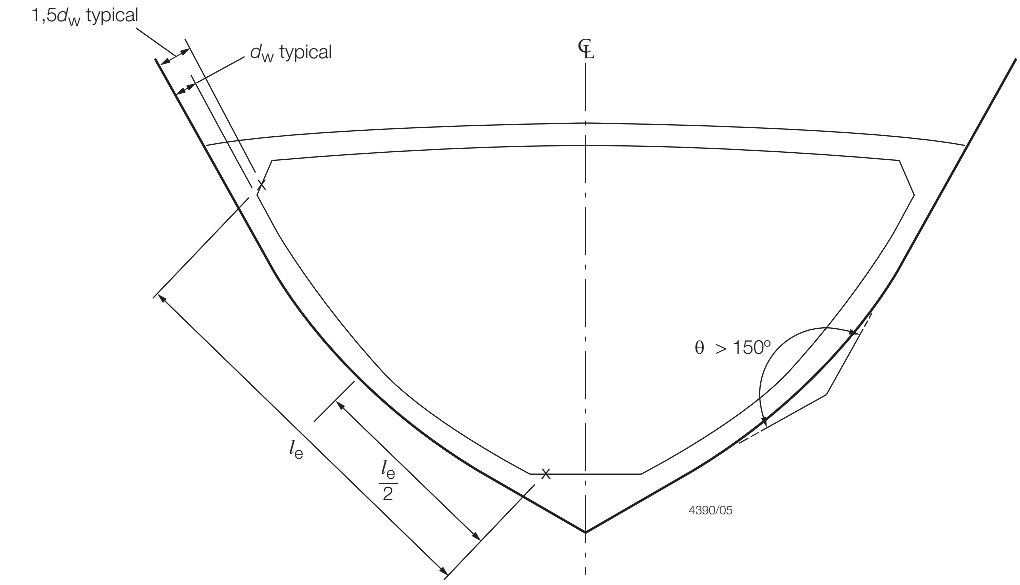


Fig. 3.1.3(c) Span points

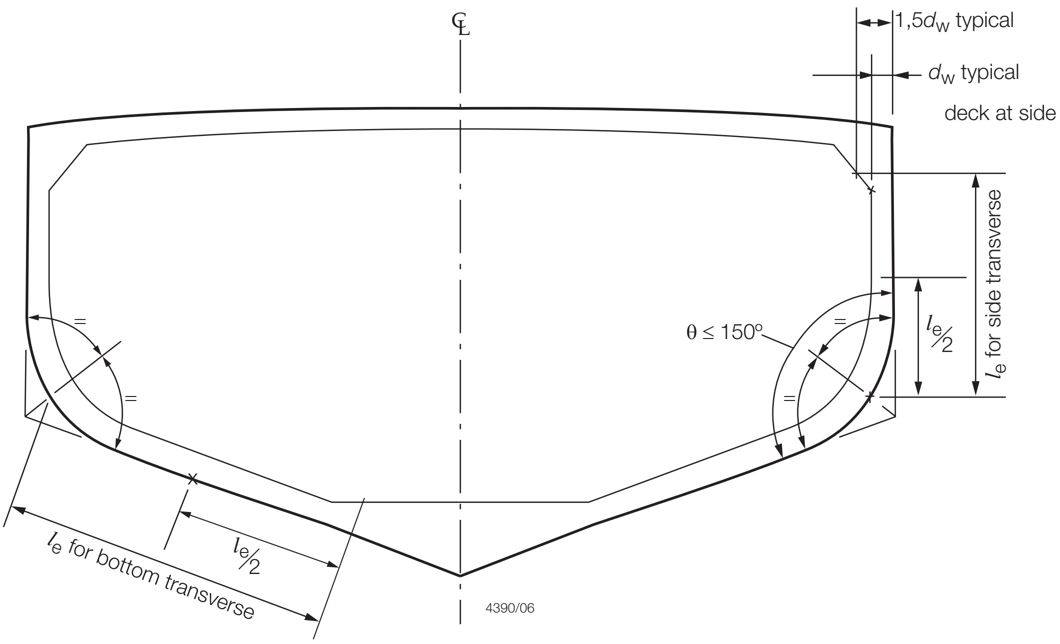


Fig. 3.1.3(d) Span points

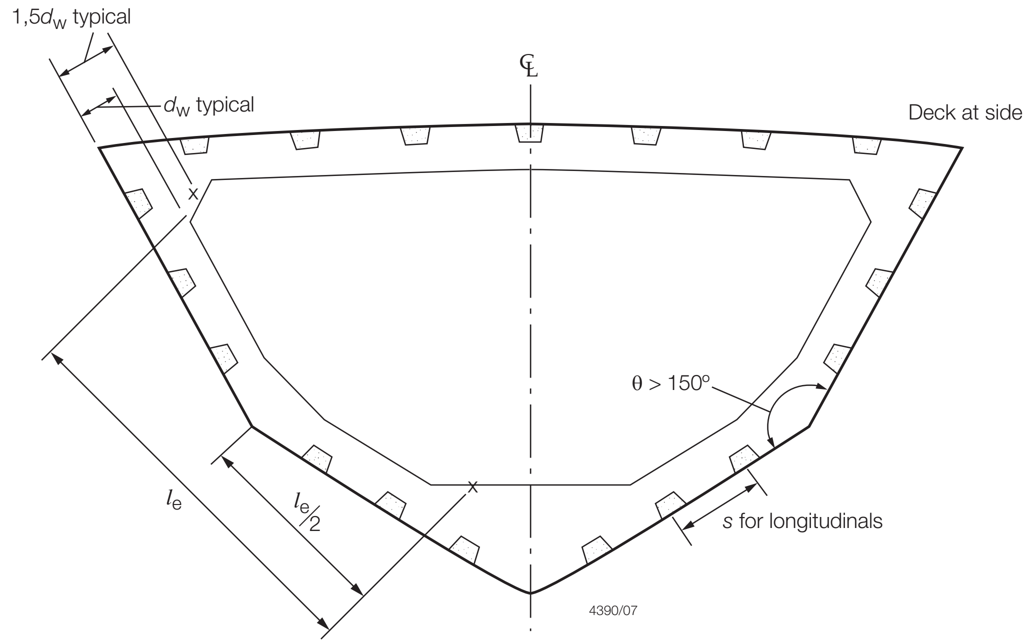


Fig. 3.1.3(e) Span points

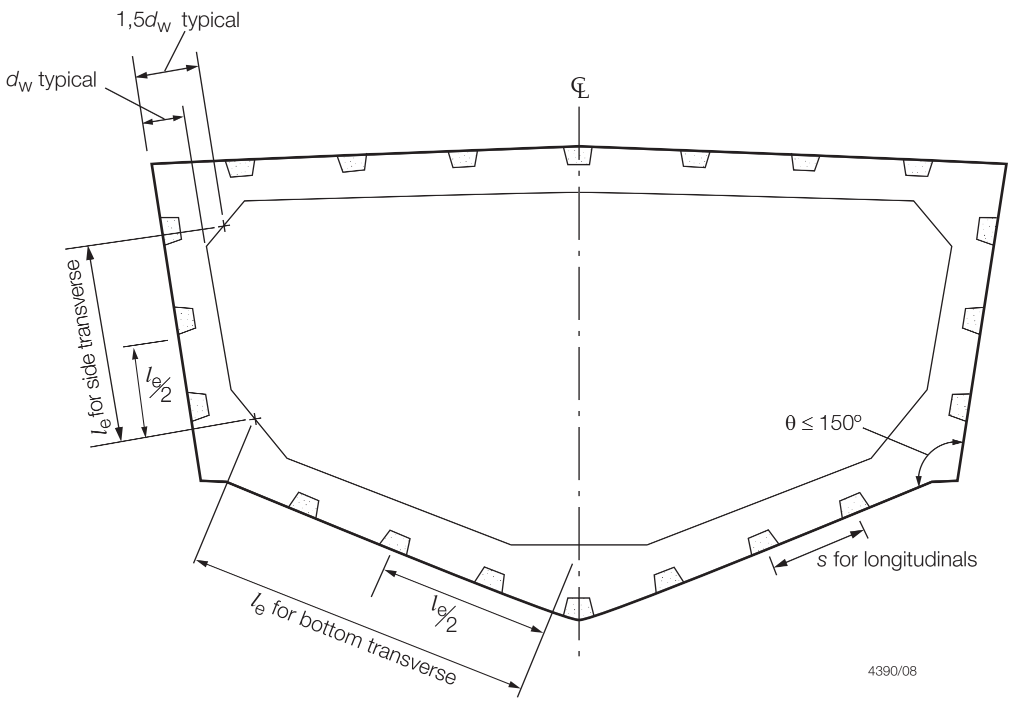


Fig. 3.1.3(f) Span points

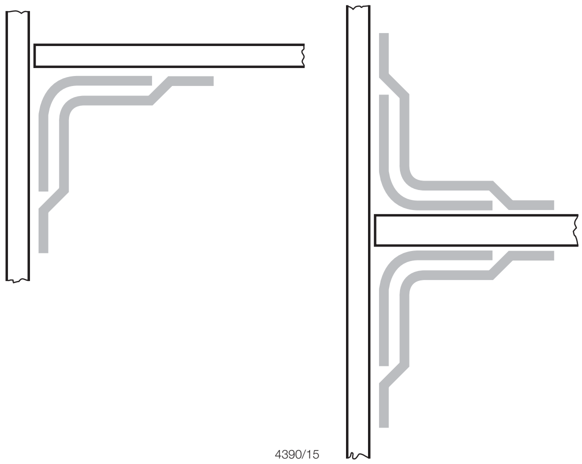


Fig. 3.1.4 Bonding angles

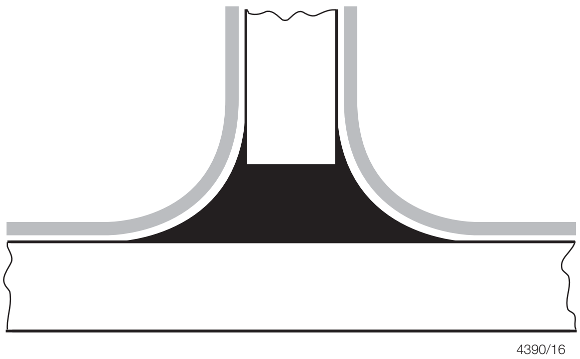


Fig. 3.1.5 Resin fillets

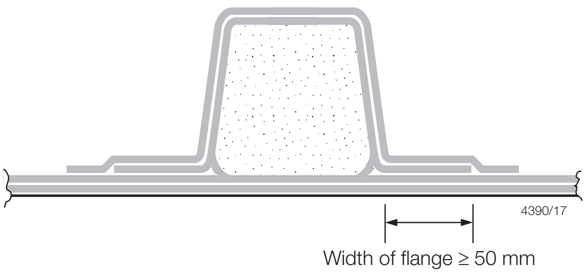


Fig. 3.1.6 Width of bonding angle

1.18.5 Double angles are normally to be used, but when this is not possible, such as where satisfactory access cannot be achieved on the reverse side, a single angle can be used provided it is suitably increased in width and weight. The weight of a single bonding angle is to be determined by direct calculation, and in no case to be taken as less than two thirds the weight of the lighter laminate being connected or 900 g/m^2 chopped fibre reinforcement or equivalent, whichever is the greater.

1.18.6 Where frames and stiffeners are of the 'top-hat' type, the width of the flange connection to the plate laminate is to be as shown in Fig. 3.1.6. The width of bonding angle is to be 25 mm for the first layer + 15 mm per each additional layer, but not less than 50 mm.

1.18.7 Where sandwich panels are to be connected the weight of bonding is to be not less than the weight of the appropriate skin. The inner and outer skins of primary sandwich structures such as bulkheads are to be effectively 'tied' by a suitable weight of reinforcement or by use of fillets and wedges of suitable compliant resin, as shown in Fig. 3.1.7.

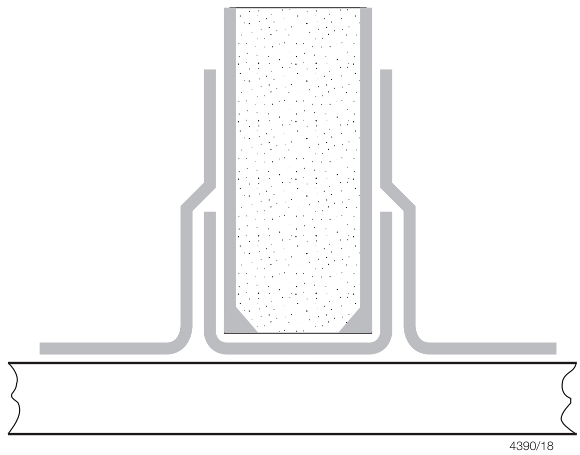


Fig. 3.1.7 Bonding ties

1.18.8 Where the floors, bulkheads, etc., are manufactured from plywood the weight of the laminate forming each angle is to be not less than 50 per cent of the weight of the equivalent thickness of bulkhead in the material used for the bonding angle or the lighter member being connected.

1.18.9 In no case is the thickness of the double bonding angle to be less than 2 mm at a glass content, by weight, of 0,5. Where a glass content is less than 0,5, the thickness is to be not less than that required to resist the same shear force using the formulae in Tables 3.1.1 and 3.1.2.

1.18.10 Alternative bonding arrangements incorporating epoxy fillets, bonded wedges, bolting, etc., may be specially considered. It is however the responsibility of the Builder to demonstrate their suitability and equivalence to the Rule requirements.

Table 3.1.11 Mechanical properties for plywood panels

Mechanical property	N/mm^2
Flexural modulus parallel to face grain, $E_{//}$	$(34{,}1N^2 - 985N + 14800)\dfrac{\rho_{WD}}{1000}$
Flexural modulus perpendicular to face grain, $E_{\perp}$	$(-31{,}5N^2 + 909N - 633)\dfrac{\rho_{WD}}{1000}$
Flexural strength parallel to face grain, $\sigma_{//}$	$(0{,}15N^2 - 4{,}52N + 79{,}5)\dfrac{\rho_{WD}}{1000}$
Flexural strength perpendicular to face grain, $\sigma_{\perp}$	$(-0{,}1N^2 + 2{,}88N + 18{,}5)\dfrac{\rho_{WD}}{1000}$

NOTES
1. N is the number of plies and is an odd number between 3 and 15.
2. ρ_{WD} is the density of plywood in kg/m^3.

1.19 Timber

1.19.1 It is presumed that, in the selection of the species of timber for a particular application, the designers will relate the known characteristics, strength, density, bending and working capabilities of the particular species to the constructional design. The mechanical properties of timbers and assumptions used for design purposes are to be clearly indicated on the submitted construction plans, *see also* Ch 2,2.17 and 1.15.1.

1.19.2 All timbers are to be identified by their botanical name.

1.19.3 The moisture content of timber which is to be glued, bonded or overlaminated is to be about 15 per cent, *see also* Ch 2,2.17.

1.20 Plywood

1.20.1 Structural plywoods are to comply with Ch 2,2.17, *see also* Ch 2,2.16.3.

Table 3.1.12 Mechanical properties for plywood on edge

Mechanical property	N/mm^2
Flexural modulus parallel to face grain, $E_{//}$	$E_{//} = (15{,}6N^2 - 400N + 9850)\dfrac{\rho_{WD}}{1000}$
Flexural modulus perpendicular to face grain, $E_{\perp}$	$E_{\perp} = (-15{,}6N^2 + 400N + 3880)\dfrac{\rho_{WD}}{1000}$
Flexural modulus at any intermediate angle, E_θ	$E_\theta = E_{//}\cos^4\theta + 4G_{IP}\cos^2\theta\sin^2\theta + E_{\perp}\sin^4\theta$
Flexural strength parallel to face grain, $\sigma_{//}$	$\sigma_{//} = (0{,}093N^2 - 2{,}4N + 58{,}2)\dfrac{\rho_{WD}}{1000}$
Flexural strength perpendicular to face grain, $\sigma_{\perp}$	$\sigma_{\perp} = (-0{,}093N^2 + 2{,}4N + 22{,}4)\dfrac{\rho_{WD}}{1000}$
Flexural strength at any intermediate angle, σ_θ	$\sigma_\theta = \left(\dfrac{\cos^4\theta}{\sigma_{//}^2} + \dfrac{\cos^2\theta\sin^2\theta}{\sigma_{//}^2\tau^2}(\sigma_{//}^2 - \tau^2) + \dfrac{\sin^4\theta}{\sigma_{\perp}^2}\right)^{-1/2}$
In-plane shear modulus parallel/perpendicular to face grain, G_{IP}	$G_{IP} = 0{,}9\rho_{WD}$
In-plane shear modulus at any intermediate angle, G_θ	$G_\theta = (E_{//} + E_{\perp} - 2G_{IP})\cos^2\theta\sin^2\theta + G_{IP}(\cos^4\theta + \sin^4\theta)$
In-plane shear strength parallel/perpendicular to face grain, τ_{IP}	$\tau_{IP} = 0{,}015\rho_{WD}$
In-plane shear strength at any intermediate angle, τ_θ	$\tau_\theta = \left[\cos^2\theta\sin^2\theta\left(\dfrac{8}{\sigma_{//}^2} + \dfrac{4}{\sigma_{\perp}^2}\right) + \dfrac{(\cos^2\theta - \sin^2\theta)^2}{\tau_{IP}^2}\right]^{-1/2}$

NOTES
1. N is the number of plies and is an odd number between 3 and 15.
2. ρ_{WD} is the density of plywood in kg/m^3.

1.20.2 The mechanical properties of the plywood proposed for use in structural applications is to be obtained from the plywood manufacturer and submitted for consideration. In the absence of such data the mechanical properties can be determined from Tables 3.1.11 and 3.1.12.

1.20.3 Where stiffeners incorporate encapsulated plywood structurally bonded to the plate laminate in accordance with 1.18.8, its effective $E_i I_i$ is to be incorporated into the Σ ($E_i I_i$) as indicated in 1.15, with the basic thickness and tensile/compressive moduli of the plywood being taken as those corresponding to the least effective over the span of the stiffener. Directional considerations for structural plywood incorporated in stiffening members are to be indicated on construction plans submitted for appraisal.

1.21 Aluminium alloy

1.21.1 The use of aluminium alloy is permitted for craft in accordance with Part 7. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.22 Steel

1.22.1 The use of steel is permitted for craft in accordance with Part 6. Where this material is to be integrated structurally, with the fibre composite structure, *see* Ch 2,2.15 and 1.15.1.

1.23 Other materials

1.23.1 Special consideration will be given to the use of other types of materials. Details of the type of material, the specification to which it was manufactured and its mechanical properties are to be submitted for appraisal, *see also* 1.15.1.

1.24 Secondary member end connections

1.24.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure are, in general, to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered on the basis of 1.17.5.

1.24.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.24.3 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the scantlings of the brackets are to be such that their section properties and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

1.24.4 The thickness of the bracket webs is to be not less than that required for the webs of the stiffening member. *See* 1.14.

1.24.5 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection are the properties reduced to less than that of the stiffener with associated plating.

1.24.6 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.24.7 Hard spots are to be avoided in way of end connections.

1.25 Scantlings of end brackets

1.25.1 Secondary members, i.e. longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are generally to be connected at their ends in accordance with the requirements of this Section. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered.

1.25.2 Where end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

1.25.3 The symbols used in this sub-Section are defined as follows:

t_w = the thickness of the bracket web, in mm
EI = section stiffness of the secondary member, in Ncm^4/mm^2

1.25.4 Typical arrangements of stiffener end brackets are shown diagrammatically in Fig. 3.1.8.

1.25.5 The section stiffness, (EI), in way of the bracket at the point to which the effective span of the stiffener, l_e, is measured is to be not less than two times the section stiffness of the basic stiffener.

1.25.6 The web thickness, t_w, and face width of end brackets are to be not less than that of the connecting stiffeners. Additionally the requirements of 1.16 are to be complied with.

1.25.7 Where brackets are of the inverted angle or 'T' bar stiffener section, their free edge is to be suitably stiffened by a flange or other equivalent means. The dimensions of the flange are to be such that the requirements of 1.16 are complied with.

1.25.8 Where the free edge of the bracket is hollowed out to form a 'soft-toe', the dimensions of the bracket arms and throat depth are to be increased such that the stiffness requirements of 1.16 are complied with.

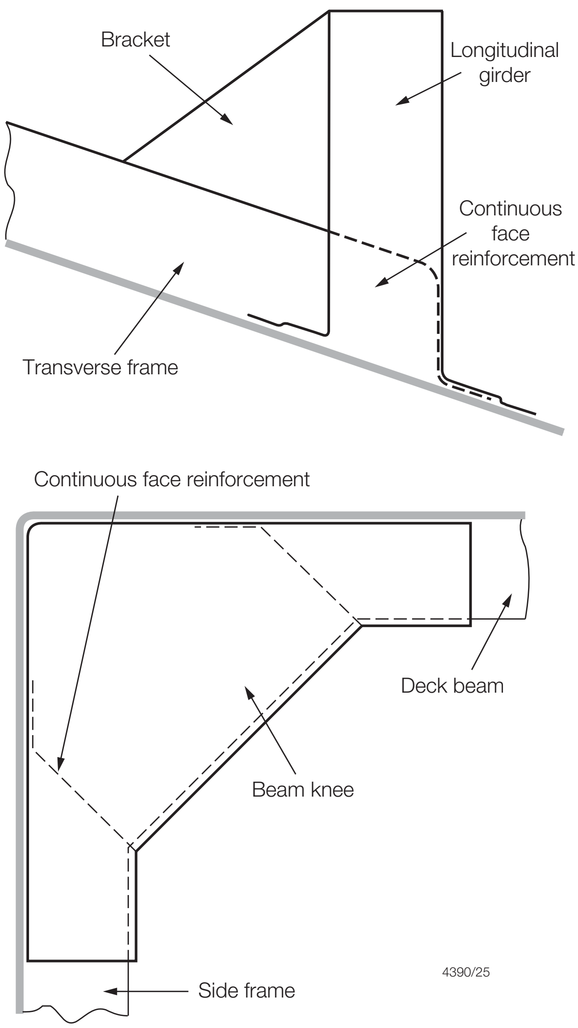


Fig. 3.1.8 Arrangement of end brackets

1.26 Primary member end connections

1.26.1 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members in tanks are to form a continuous line of support and wherever possible, a complete ring system.

1.26.2 The members are to have adequate lateral stability and web stiffening and the structure is to be so arranged as to minimise hard spots and other sources of stress concentration.

1.26.3 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member.

1.26.4 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended for at least two frame spaces, or equivalent, beyond the point of support before being tapered.

1.26.5 Where primary members are subject to concentrated loads, particularly if these are out of line with the member web, additional strengthening will, in general, be required.

1.26.6 The thicknesses of the bracket webs are, in general, to be not less than those of the primary member webs. Where brackets are of the plate type, the free edge of the bracket is to be adequately stiffened and the plate positioned to limit any hard spot.

1.26.7 Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

1.26.8 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Proposals to fit brackets of reduced scantlings, or alternative arrangements, will be considered.

1.26.9 Connections between primary members forming a ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

1.27 Arrangements and details

1.27.1 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the section stiffness (EI), reduced to less than that of the stiffener with associated plating.

1.27.2 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

1.28 Web stability

1.28.1 Primary members of 'top-hat' or single plate laminate construction type section are to be supported by tripping brackets at, in general, four for top hat and alternate frame spacings for plate, of secondary stiffening members respectively.

1.29 Openings in the webs of stiffening members

1.29.1 Where openings are cut in the webs of stiffening members, the depth of the opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth

from the face laminate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

1.29.2 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are to be suitably sealed with resin and/or be over laminated. Exposed edges in way of cut-outs in sandwich panels and top hat type stiffening members are to be overlaminated with a weight of laminate not less than the lower of the two skins which form the panel (or stiffener) or 2 mm in thickness whichever is the greater.

1.29.3 Cut-outs for the passage of secondary members are to be arranged so as to minimise the creation of stress concentrations. To avoid excessive use of filler material the breadth of cut-out is to be kept as small as necessary and the fit as accurate as practicable. Suitable fillets are to be arranged to ensure efficient bonding.

1.29.4 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

1.30 Continuity and alignment

1.30.1 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

1.30.2 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment.

1.30.3 Pillars and pillar bulkheads are to be fitted in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

1.30.4 Continuity is to be maintained where primary members intersect and where the members are of the same depth, *see also* LR's *Guidance Notes for Structural Details*.

1.30.5 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

1.30.6 The toes of brackets, etc., are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off in accordance with Fig. 3.4.1 in Chapter 3.

1.31 Arrangements at intersection of continuous secondary and primary members

1.31.1 Cut-outs for the passage of secondary members through the webs of primary members, and the related bonding arrangements, are to be so designed as to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be examined. Longitudinals will be required to have double bonding angles which may require to be locally increased in weight in areas of high stress, such as under bulkheads, machinery seating, mast steps, etc. The increased shear stresses in these areas are to be examined.

1.31.2 It is recommended that the web plate connection to the hull envelope, or bulkhead end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in Fig. 3.4.1, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

1.31.3 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

■ *Section 2*
Minimum thickness requirements

2.1 General

2.1.1 Structural laminates, used for both single skin and sandwich construction are, in general, to incorporate not less than 40 per cent, by weight, of woven or cross-ply reinforcement.

2.2 Single skin laminate

2.2.1 The minimum thicknesses of single skin laminates are as indicated in the appropriate Sections.

2.3 Sandwich skin laminate

2.3.1 The minimum amount of reinforcement in single skin laminates which form the inner and outer skins of sandwich panels are as indicated in 2.5.1. Where the structural requirements for thickness of either the bottom shell outer skin, or inner skin in way of an integral tank, is less than that required by 2.5.1, a 20 per cent reduction in the minimum amount of reinforcement will be acceptable, conditional upon a vacuum test to demonstrate the watertight integrity and also an impact test for impact resistance of the laminate, *see* 2.9.2.

2.4 Laminate thickness of single skin laminates

2.4.1 The Rule minimum skin thicknesses for single skin laminates as determined from the appropriate Sections of the Rules are to be corrected for craft type irrespective of the reinforcement being used; the corrected minimum skin thickness of side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

Single skin laminates:

$t_T = \omega\, t_{min}$

where

ω = Service Type Correction Factor given in Table 3.2.1
t_T = Rule minimum thickness corrected for craft type, in mm.
t_{min} = Rule basic minimum thickness, in mm.

2.4.2 All minimum thicknesses of laminate for both stiffener and single skin laminate components are based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is less than 0,5, the required minimum thicknesses are to be determined from:

$t_{fc} = t_{0,5}\,(1{,}65 - 1{,}3 f_c)$ mm

where

t_{fc} = minimum thickness at actual laminate fibre content, in mm
$t_{0,5}$ = Rule basic minimum laminate thickness at fibre content, by weight, of 0,5.

2.4.3 The equation in 2.4.2 relates to polyester 'E' glass laminates. Other laminates will be considered on an equivalence basis.

2.5 Minimum skin reinforcement in sandwich laminates

2.5.1 The minimum amount of reinforcement in single skin laminates, which form the inner and outer skins of sandwich laminates, is given in Table 3.2.2. The minimum amount of reinforcement is to be modified in accordance with 2.5.2 to 2.5.4.

2.5.2 The Rule minimum amount of reinforcement in 2.5.1 is to be corrected for craft type, irrespective of the reinforcement being used; the corrected minimum amount of reinforcement in the side, bottom, transom, wet-deck, vehicle deck and weather decks is to be determined from:

$W_T = \omega W_{min}$

where

W_T = Rule minimum amount of reinforcement corrected for craft type, in g/m^2
W_{min} = minimum amount of reinforcement given in Table 3.2.2
ω = Service Type Correction Factor given in Table 3.2.1.

Table 3.2.1 Service type correction factor (ω)

Service type notation	ω
Cargo	1,1
Passenger	1,00
Patrol	1,00
Pilot	1,1
Yacht	1,00
Workboat – Motor fishing vessel	1,2

2.5.3 The Rule minimum amount of reinforcement in Table 2.5.1 is to be corrected for craft length, irrespective of the reinforcement being used; the corrected amount of reinforcement is to be determined from:

$W_{Lc} = K_L W_{min}$

where

W_{Lc} = Rule minimum amount of reinforcement corrected for craft length
W_{min} = minimum amount of reinforcement given in Table 3.2.2
K_L = craft length correction factor
= $1{,}0 - f_{LS}$ for $L_R \le 15$ m
= 1,0 for $L_R \ge 35$ m
Intermediate values of K_L are to be determined by linear interpolation
f_{LS} = sandwich skin length factor given in Table 3.2.2 for mono-hull craft and Table 4.2.1 in Chapter 4 for multi-hull craft
= 0,0 for all sandwich panels in cargo, pilot and workboat crafts
L_R = Rule length, in metres, as defined in Pt 3, Ch 1,6.2.

2.5.4 The minimum amount of reinforcement is based on an assumed fibre content, f_c, of 0,5. Where the fibre content by weight, f_c, is greater than 0,5, the required minimum amount of reinforcement is to be determined from:

$W_{fc} = K_V W_{0,5}$

where

W_{fc} = minimum amount of reinforcement at actual laminate fibre content, in g/m^2
$W_{0,5}$ = Rule minimum amount of reinforcement laminate thickness at fibre content, by weight, of 0,5, in g/m^2
K_V = fibre volume correction factor for laminates with fibre content, by weight, greater than 0,5

$$= \left(\frac{1 + \dfrac{\zeta_F}{\zeta_R}}{1 + \left(\dfrac{\zeta_F}{\zeta_R}\right)\left(\dfrac{1 - f_c}{f_c}\right)} \right)^{0,67}$$

f_c, ζ_F and ζ_R are as defined in 1.5.1.

2.5.5 In areas where impact loads are not likely to occur, special consideration will be given to laminates with amount of reinforcement less than that required by 2.5.1, provided that all of the structural strength requirements of the Rules are complied with.

Table 3.2.2 Minimum amount of reinforcement in sandwich laminate skins

Panel location	Minimum amount of reinforcement, W_{min} (g/m^2)		Sandwich skin length factor, f_{LS}
	Glass	Carbon/ Aramid	
Integral tanks, fluid barrier skin	3650	2700	0,0
Hull bottom, outer skin	3650	2700	0,33
Hull bottom, inner skin	2850	2100	0,33
Side shell, outer skin	3250	2400	0,33
Side shell, inner skin	2450	1950	0,33
Inner bottom, outer skin	3650	2700	0,33
Inner bottom, inner skin	2850	2100	0,33
Double bottom plate floor	1650	1300	0,0
Watertight bulkhead	1650	1300	0,0
Deep tanks, exterior skin	2450	1950	0,0
Deep tanks, fluid barrier skin	3250	2400	0,0
Strength/weather deck, outer skin	2450	1950	0,33
Strength/weather deck, inner skin	1650	1300	0,0
Lower deck/within deckhouse, accommodation decks	1650	1300	0,0
Cargo deck, outer skin	2450	1950	0,0
Cargo deck, inner skin	1650	1300	0,0
Superstructure sides	1650	1300	0,0
Superstructure front	2050	1500	0,0
Superstructure aft	1650	1300	0,0
Superstructure top	1650	1300	0,0
Coach roof	1650	1300	0,0
Machinery casings	2050	1500	0,0
Bulwarks	1650	1300	0,0

NOTE
The minimum amount of reinforcement in hybrid laminates will be individually considered on an equivalence basis. *See* 2.9.2.

2.6 Integral tank structure

2.6.1 The minimum thickness of laminate for all stiffening members passing through, or forming the boundary of integral oil fuel and water tanks is to be not less than 4,5 mm irrespective of fibre content.

2.6.2 Where the boundaries of integral oil fuel and water tanks are of sandwich skin construction the minimum amount of reinforcement in the laminate providing the fluid barrier, without satisfactory material testing, is to comply with the requirements of 2.5.1, *see* 2.3.1.

2.6.3 Where the boundaries of integral oil fuel and water tanks are of single skin construction, in no case is the tank laminate thickness, determined in accordance with 7.4, to be less than 5,0 mm irrespective of fibre content.

2.7 Novel features

2.7.1 Where the Rules do not specifically define the requirements for novel features, the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, Recognised Standards and good practice, and are to be submitted with the relevant construction plans for appraisal, *see also* Ch 1,2.6.

2.8 Impact considerations

2.8.1 Due consideration is to be given to the scantlings of all structures which may be subject to local impact loadings. Impact tests may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.8.2 The minimum skin thickness requirements may, subject to the agreement of LR, be reduced provided that suitable impact tests are carried out to demonstrate that the proposed laminates have not less than the equivalent impact resistance to that of a laminate which satisfies the Rule minimum thickness. In addition it is assumed that this reduced laminate satisfies the structural strength and deflection requirements of the Rules.

2.9 Sheathing

2.9.1 Areas of shell and deck which are subject to additional wear by abrasion e.g., passenger routes, working areas of fishing craft, forefoot region, etc, are to be suitably protected by local reinforcement as given in 3.14 or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc., as appropriate. Details of such sheathing and the method of attachment are to be indicated on the relevant construction plans submitted for appraisal.

2.9.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the structural integrity of the laminate or the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting is to be such that damage to the sheathing will not impair the watertight integrity of the attachment to the hull.

Section 3
Shell envelope laminate

3.1 General

3.1.1 The requirements in respect of the general plating elements of the shell envelope, excluding the deck, are contained within this Section.

3.2 Keel plate

3.2.1 The width, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$b_K = 7{,}0L_R + 340$ mm

$t_K = \sqrt{k_t}\ (5{,}0L_R^{0{,}45})$ mm

where

$k_t = \dfrac{152}{\sigma_f}$

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the keel plate material, in N/mm^2, *see* 1.12.6.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell plating.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP), above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by 3.3 for the stem. Laminate tapers are to be in accordance with Ch 2,3.9.

3.2.4 Where the bottom shell is of sandwich construction the keel is, in general, to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

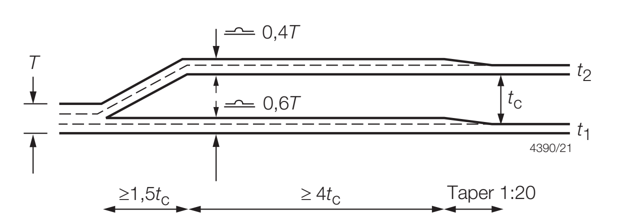


Fig. 3.3.1
Single skin/sandwich skin intersection detail

3.2.5 For large or novel craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Stem plate

3.3.1 The thickness of the plate stem, t_s, is not to be taken as less than that given by the following expression:

$t_s = \sqrt{k_t}\ (0{,}29L_R + 9)$ mm

where

k_t = as defined in 3.2.1

L_R = Rule length, in metres, as defined in 1.5.1

σ_f = ultimate flexural strength of the stem plate material, in N/mm^2, *see* 1.12.6.

3.3.2 In no case is the thickness of the plate stem to be taken as less than the thickness of the adjacent side shell plating.

3.3.3 The width of the plate stem is to be not less than the width of keel as required by 3.2.1.

3.3.4 Plate stems are to be supported by horizontal diaphragms and, where the stem radius is large, a centreline stiffener or web may be required.

3.3.5 Where the side shell is of sandwich construction the stem is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of stem is to comprise both the inner and outer skins of the adjacent side shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate stem and sandwich bottom structure is to be in accordance with Fig. 3.3.1.

3.3.6 For large or novel craft, the scantlings of the stem will be specially considered, *see also* 5.11.

3.4 Bottom

3.4.1 The bending moment assumed to be carried by the bottom shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for high speed or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.4.2 and 3.4.4 respectively.

3.4.2 An estimate of the thickness of **bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 5,5 mm.

3.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and

1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.4.5 The amount of reinforcement in laminates which form the skins of a sandwich laminate is to comply with the requirements of 2.5.1, *see* 2.3.1.

3.4.6 For all craft types, the minimum bottom shell thickness as required by 3.4.3 and 3.4.5 is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

3.4.7 Additionally, for high speed craft, the minimum thickness requirements for the bottom shell between the bilge tangential points or chines and the chine line or 150 mm above the static load waterline, whichever is the greater, is not to be less than determined for the side shell using the side shell impact pressure or the bottom shell hydrostatic or pitching pressures associated with a displacement or semi-displacement type craft whichever is the greater, *see* Fig. 3.3.2.

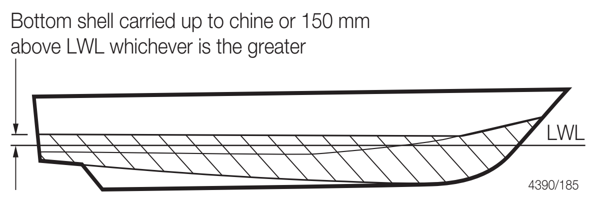


Fig. 3.3.2 Extent of bottom shell

3.4.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.4.2 and 3.4.4, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.5 Side

3.5.1 The bending moment assumed to be carried by the side shell plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.2 and 3.5.4 respectively.

3.5.2 An estimate of the thickness of **side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

3.5.4 An estimate of the stiffness *EI*, thickness of single skin plating for outer and inner skins of the **side sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

3.5.6 Special consideration may be given to laminate thicknesses lesser than that required by 3.5.3 and 3.5.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

3.6 Sheerstrake

3.6.1 The sheerstrake, is in general, to be taken as the side shell, locally reinforced in way of deck/hull connection and fender attachment. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service, but is not to be less than that required by 3.14.

3.6.2 The fendering arrangements for all craft types are the responsibility of the designers/Builders and are outside the scope of classification.

3.6.3 Where the pressure or impact loadings that a particular type of craft will experience in service are considered by the Builder, or subsequent Owner, to be not covered by, or be greater than, those indicated in Part 5 of the Rules, details of the loadings together with the calculations of how these will be satisfactorily distributed into the craft's structure, are to be submitted for consideration with the relevant construction plans.

3.6.4 The arrangements indicated in 3.6.5, 3.6.6, 4.19.5 and 4.19.6 for pilot and fishing craft are for the guidance of the Builder and subsequent Owners/operators of the craft. Where the intended service for either of these types of craft, or other types of craft which may be subject to loadings resulting from contact with other craft, jetties or similar loading or boarding facilities, is such that the loadings are greater than those that can be satisfactorily distributed into the craft's structure by the arrangements indicated, the strengthening arrangements are to be increased accordingly.

3.6.5 For **pilot craft** and other general workboats which may be subject to repeated impact loadings from contact with other craft, etc., the sheerstrake laminate and stiffening arrangements in way are to be increased locally. An increase in laminate weight of not less than 50 per cent of the side shell laminate weight is to be fitted, extending in general from the bow aft over a distance of $0{,}33L_R$ or 500 mm aft of the point at which the craft reaches its greatest breadth, whichever is the greater, and around the quarters. The additional weight is to extend forward of the quarter and over the transom for a

distance of 0,075L_R or 1,0 m, whichever is the greater. This reinforcement is in general to extend from the deck edge to below the first longitudinal stiffener, or a vertical distance equivalent to 1/3 the freeboard height, whichever is the greater. The additional laminate weight is then to be tapered out to the side shell laminate weight in accordance with the Rules, *see* 3.14.2. For increase in stiffening arrangements, *see* 4.19. Where the side shell is of sandwich construction then in way of the sheerstrake the two skins of the sandwich are to combine and form a single skin. The weight of this single skin is to be the Rule single skin reinforced in accordance with the above or 1,5 times the total sandwich skin laminate weight whichever is the greater. The arrangement and distribution of this additional laminate between the skins in way of the taper is to be in accordance with 3.2.4. Where fendering can be considered to act as a chine/spray rail the extent of bottom shell laminate is, in general, to be to above the lower fender.

3.6.6 **Fishing craft** are, in general, to have their shell laminate as required to satisfy the Rule loadings, increased by 20 per cent. Additionally the side shell is not to be taken as less than the bottom shell weight, and where there are gallows, gantries, nets, or lines, etc., the laminate in way is to be further increased locally and/or suitably protected by sheathing in timber, steel or other means. Where the hull is of sandwich construction in way of the sheerstrake the laminate is to combine to form a single skin as indicated in 3.6.2.

3.6.7 Individual consideration will be given to lesser scantlings than those required by 3.6.3. for fishing craft used for pleasure, light duties, etc. Details of the service are to be submitted for appraisal.

3.7 Transom boundary reinforcement

3.7.1 Additional reinforcement is to be moulded into the transom boundary.

3.7.2 For single skin construction, the total weight of reinforcement is to be not less than twice the weight of the adjacent side shell plate laminate, but need not be greater than Rule keel weight as required by 3.2.

3.8 Chine reinforcement

3.8.1 Additional reinforcement is to be moulded into the chine line knuckle boundary, chines and other areas where there is a change of section.

3.8.2 The chine line knuckle is to be reinforced as required by 3.7 for the transom boundary.

3.8.3 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of all chines are to submitted for consideration, *see also* LR's *Guidance Notes for Structural Details*.

3.9 Skeg

3.9.1 The thickness of the skeg plating is, in general, to be not less than the thickness of the keel at bottom or 1,5 times the thickness of the bottom shell on the sides, whichever is the greater, *see also* 5.10.

3.10 Shell openings

3.10.1 Openings are to have smooth edges and well rounded corners. Exposed edges in way of cut-outs in single skin/plate laminate are, in general, to be suitably sealed over laminating with not less than 2 x 450 g/m^2 CSM (or equivalent) reinforcements. Alternative arrangements demonstrating the equivalent protection to the ingress of moisture into the laminate will be individually considered in association provided on the relevant plans.

3.10.2 The exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the outer skin of the sandwich panel.

3.10.3 Where other than an epoxy resin system is used the first layer of reinforcement, as required by 3.10.1 and 3.10.2, is, in general, to be CSM with a weight not exceeding 300 g/m^2.

3.10.4 Sea inlet boxes are to have well rounded corners and, so far as possible are to be kept clear of the bilge radius. Arrangements are to be made to maintain the continuity of structural strength in way of the openings.

3.11 Appendages

3.11.1 The scantlings of appendages will be subject to special consideration on the basis of the Rules and the design loadings anticipated, but are in no case to be taken as less than that of the surrounding structure.

3.12 Fin and tuck

3.12.1 Additional reinforcement is to be moulded into the fin and tuck areas of yachts which have either internal fixed ballast or external attached ballast keels, *see also* Part 16.

3.12.2 For single skin construction the total weight of reinforcement is not to be less than 1,50 times the weight of the adjacent bottom shell plate laminate, but need not be greater than the Rule keel weight as required by 3.2.

3.13 Transom

3.13.1 The thickness of the stern or transom is to be not less than that required by 3.4 and 3.5 as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.14 Local reinforcement

3.14.1 The hull and deck are to be locally increased in thickness in way of fittings for rudder tubes, propeller brackets, passenger routes, vehicle lanes, etc. The amount of increase is to be not less than 50 per cent of the adjacent plate laminate. Details of such reinforcement are to be submitted.

3.14.2 Local reinforcement is in general to extend under the adjacent supporting structure and then be tapered gradually to the base laminate thickness over a distance of not less than 20 times the difference in thickness, *see* Fig. 3.3.3.

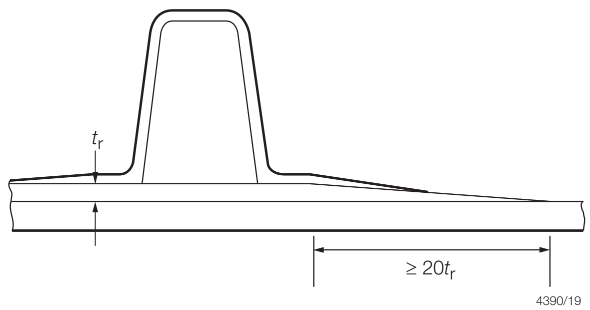


Fig. 3.3.3 Arrangement of local reinforcement

3.14.3 The amount of material laid 'wet on wet' is to be limited to avoid excessive heat generation.

3.15 Hull laminate arrangement

3.15.1 The hulls of all craft with a service speed of 25 knots or greater are to be moulded, such that following local impact, damage progressive stripping of surface reinforcements will not occur. This may be achieved by arranging all hull reinforcements as shown in Fig. 3.3.4.

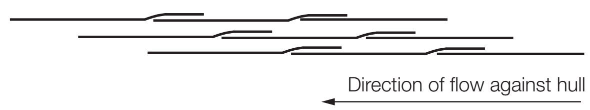


Fig. 3.3.4 Arrangement of hull reinforcement

3.15.2 Details of the laminate sequence and direction of orientation are to be indicated in the laminate schedule as required by Ch 2,3.3.7.

3.15.3 It is recommended that woven reinforcements be laid transversely to minimise the susceptibility to progressive stripping of hull laminates following local impact.

3.15.4 Special consideration is to be given to hull laminates where high glass content is proposed and where orthophthalic resins are used.

3.16 Novel features

3.16.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for appraisal.

■ *Section 4*
Shell envelope framing

4.1 Application

4.1.1 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 General

4.2.1 To determine the required scantlings, the formulae indicated in 1.14 are, in general, to be used in conjunction with the design loadings specified in Part 5.

4.3 Symbols and definitions

4.3.1 Symbols and definitions for use throughout this Chapter are as given in 1.5.1 or specified in the appropriate Section.

4.4 Bottom longitudinal stiffeners

4.4.1 The bottom longitudinals are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.4.2 Bottom longitudinals are to be continuous through the supporting structures.

4.4.3 Where it is impracticable to comply with the requirements of 4.4.2, or where it is desired to terminate the bottom longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.4.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.4.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom longitudinal primary stiffeners

4.5.1 Bottom longitudinal primary stiffeners are to be supported by bottom deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.5.2 Bottom longitudinal primary stiffeners are to maintain their continuity through the supporting structures.

4.5.3 Where it is impracticable to comply with the requirements of 4.5.2, or where it is desired to terminate the bottom longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.5.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.5.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom transverse stiffeners

4.6.1 Bottom transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.6.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.6.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom transverse frames

4.7.1 Bottom transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.7.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.7.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.8 Bottom transverse web frames

4.8.1 Bottom transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.8.2 Where it is impracticable to comply with the requirements of 4.8.1, or where it is desired to terminate the bottom transverse web frames in way of bulkheads or integral tank boundaries, etc., they are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.8.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.8.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.9 Side longitudinal stiffeners

4.9.1 The side longitudinals are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.9.2 Side longitudinals are to be continuous through the supporting structures.

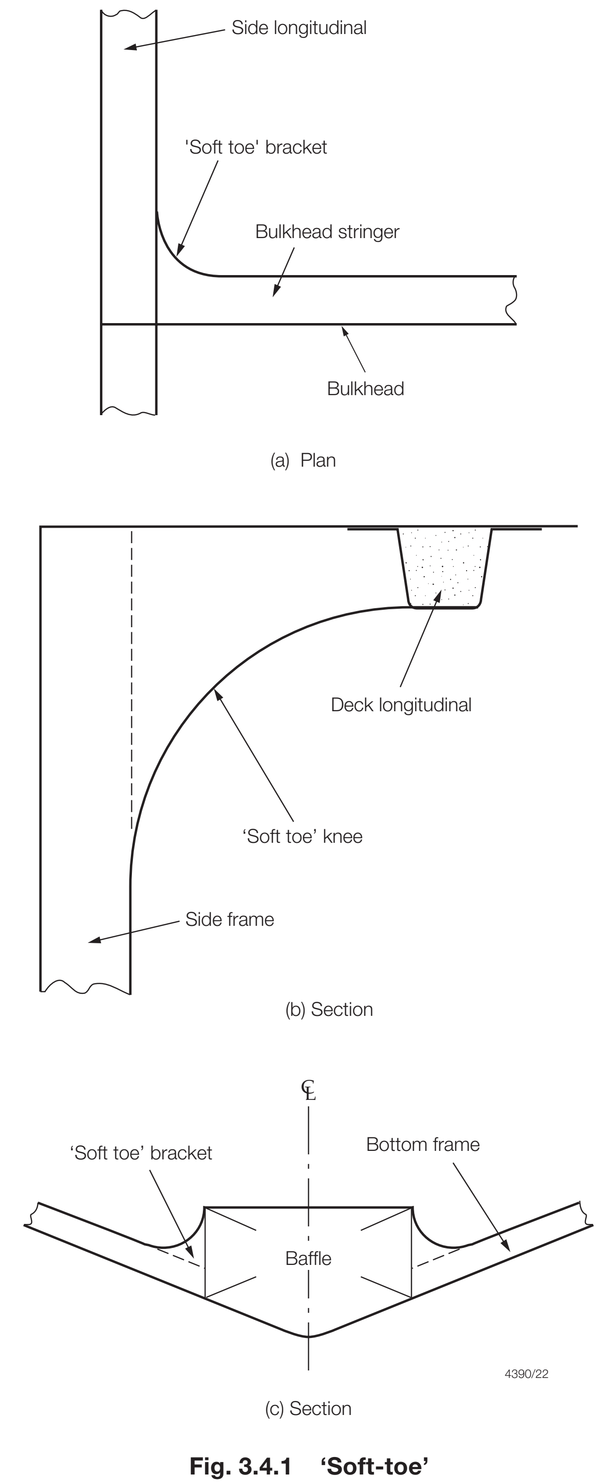


Fig. 3.4.1 'Soft-toe'

4.9.3 Where it is impracticable to comply with the requirements of 4.9.2, or where it is desired to terminate the side longitudinals in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

4.9.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.9.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.10 Side longitudinal primary stiffeners

4.10.1 Side longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.10.2 Side longitudinal primary stiffeners are to maintain their continuity through the transverse bulkheads and other supporting structures.

4.10.3 Where it is impracticable to comply with the requirements of 4.10.2, or where it is desired to terminate the side longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.11 Side transverse stiffeners

4.11.1 Side transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

4.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.12 Side transverse frames

4.12.1 Side transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side transverse web frames

4.13.1 Side transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their head and heel connections to deck beams and bottom web frames respectively.

4.13.2 Where it is impracticable to comply with the requirements of 4.13.1, or where it is desired to terminate the side transverse web frames in way of side longitudinal primary stiffeners, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections,to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

4.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Grouped frames

4.14.1 For the purposes of satisfying Rule requirements, frames may, subject to agreement by LR, be grouped. The number of frames in any group shall not in general exceed five. The summation of section stiffness, EI, for the group of frames is not to be less than the summation of the Rule requirements for the individual framing members. In addition, in no case is the proposed scantlings of an individual framing member within the group to be less than ninety per cent of the Rule value for that member.

4.15 Grillage structures

4.15.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* 1.3.

4.15.2 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

4.15.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

4.16 Combined framing systems

4.16.1 Where longitudinal and transverse primary stiffeners form grillage structures the scantlings may be derived in accordance with 4.15.

4.17 Floating framing systems

4.17.1 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, EI, of the primary stiffening members, i.e. the full section stiffness, EI, is to be provided by the primary stiffening member only.

4.18 Frame struts

4.18.1 Where struts are fitted to side shell transverse web frames or longitudinal primary stiffeners to carry axial loads the strut cross-sectional area is to be derived as for pillars in Section 10. If fitted at the stiffener half span point the stiffener section modulus may be taken as half the modulus derived from the general equations for the stiffening member being considered.

4.18.2 Design of end connections is to be such that the strut loads can be efficiently transmitted into the supporting structure.

4.19 Fenders and reinforcement in way

4.19.1 The design of and responsibility for the fendering on any craft rests with the designer and prospective Owner and are outside the scope of classification scantling approval requirements. The arrangement for fendering fitted should not be detrimental to the general working of the structure and therefore the requirements indicated in 4.19.2 to 4.19.6 are provided as recommendations of the areas requiring special consideration by the designer and Builder.

4.19.2 Wood belting and fenders, which may be subject to considerable impact load, are to be bedded down on a flexible sealing compound or a neoprene type gasket to ensure watertightness. The bolts are to be both adequate in number and size and, where practicable, reeled to prevent perforation of the laminate. Substantial plate washers or, where practicable, a continuous backing plate are to be provided. The arrangement for the attachment of the fender should, in general, be arranged so that where sections of the fender are damaged or torn, the watertight integrity of the hull is not impaired.

4.19.3 The laminate in way of such fittings is to be substantially increased in thickness to prevent overloading, and depending on the position, a back-up block of wood, plastic or metal may be required.

4.19.4 For craft such as pilot craft, fishing craft, etc., which may be subject to repeated impact loadings from contact with other craft whilst in service, due consideration is to be given to increasing the scantlings of stiffening members in way of the fenders. Details of these increased scantlings, anticipated loadings and calculations, are to be indicated on the submitted plans, *see also* 3.6.3 and 3.6.4.

4.19.5 **Pilot craft** are, in general, to be fitted with large knees in way of the sheerstrake in areas as indicated in 3.6.5. The knees are to be aligned between the transverse frames and the deck beams. The thickness of the webs for these knees is to be twice that required by 1.16 or 6 mm at a fibre content by weight, of 0,5. Where the fibre content is less than 0,5 the minimum thickness is to be increased by the factor k_c as follows:

$$t_{min} = 6k_c$$

where

$k_c = 1,65 - 1,3f_c$

f_c is as defined in 1.5.1.

In the case of longitudinally framed craft, web frames with knees are to be fitted at a spacing of generally no greater than 500 mm. A side longitudinal with a section modulus of, in general, twice that of the Rule longitudinal for the web frame spacing is to be positioned just below the lower fendering to carry the load associated with the dynamic loading from pitching and rolling. Consideration is also to be given to the termination of such brackets by use of a 'soft-toe' in way of the deck.

4.19.6 **Fishing craft** engaged in pair trawling and other modes of fishing, and which may be subject to repeated impact loading from contact with the other craft, are to have additional stiffening fitted in way of the impact areas. This may be in the form of large knees, intermediate knees or substantial fendering/rubbing strakes. Additionally, the shell and deck in way of all working areas are to be suitably sheathed.

■ *Section 5*
Single bottom structure and appendages

5.1 General

5.1.1 The requirements of this Section provide for single bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

5.1.2 All girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity particularly in way of skegs. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

5.1.3 Particular attention is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face reinforcement of such stiffening members is to be effectively continuous.

5.1.4 The single bottom structure in way of the keel, skeg and girders is to be sufficient to withstand the forces imposed by dry-docking the craft.

5.1.5 The breadth and thickness of plate keels are to comply with the requirements detailed in 3.2. *See also* 3.9.1.

5.2 Centreline girder

5.2.1 In craft with single bottoms, a centreline girder is, in general, to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.2.2 Centreline girders may be in the form of intercostal or continuous top hat or plate webs. Where the girder is intercostal, additional bracketing and local reinforcement as given in 3.14 is to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.2.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.4.

5.2.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by 1.16. or as determined as follows, whichever is the greater:

$$t_w = 1,28\sqrt{k_A}\left(\sqrt{L_R} + 1\right) \text{ mm}$$

in no case is t_w to be taken less than 5,0 mm

where

k_A and L_R are as defined in 1.5.1.

5.2.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.2.4.

5.2.6 The face area of the centre girder, A_f, is to be not less than:

$A_f = 1{,}18 L_R k_A$ cm^2

where

k_A and L_R are as defined in 1.5.1.

5.2.7 The face area of the centre girder outside 0,5L about midships may be reduced to 80 per cent of the value given in 5.2.6.

5.2.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.2.9 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3 Side girders

5.3.1 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.3.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.3.3 The face area of side girders, A_f, is not to be taken as less than:

$A_f = 0{,}82 L_R k_A$ cm^2

where

k_A and L_R are as defined in 1.5.1.

5.3.4 The face thickness, t_f, is not, in general, to be less than the web thickness of the side girder.

5.3.5 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater:

$t_w = 1{,}28 \sqrt{k_A L_R}$ mm

where

k_A and L_R are as defined in 1.5.1

in no case is t_w to be taken less than 5,0 mm.

5.3.6 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.3.5.

5.3.7 In addition, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

5.3.8 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3. and 7.4 respectively.

5.4 Floors, general

5.4.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.4.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are, in general, to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.4.3 The overall depth of transverse floors at the centreline, d_f, is not to be taken as less than:

when $B < 10$ m $\quad d_f = 40\,(B + 0{,}85D)$ mm

when $B \geq 10$ m $\quad d_f = 40\,(1{,}5B + 0{,}85D) - 200$ mm

where

B is as defined in 1.5.1.

5.4.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than that required by 1.16 or as determined as follows, whichever is the greater:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_f}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \text{ mm}$$

where

d_f is as defined in 5.4.3.

k_A and s are defined in 1.5.1

In no case is t_w to be taken less than 5,0 mm.

5.4.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 If side frames are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.4.7 The face area of floors, A_f, is not to be taken as less than:

$A_f = 0{,}82 L_R k_A$ cm^2

where

k_A and L_R are as defined in 1.5.1.

5.4.8 The thickness of the face reinforcement, t_f, is to be not less than the web thickness.

5.4.9 In addition, the requirements of 4.8 for bottom transverse web frames are to be complied with.

5.4.10 Floors are generally to be continuous from side to side.

5.4.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.4.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube where applicable.

5.4.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

5.5 Floors in machinery spaces

5.5.1 Floors within machinery spaces are to comply with the requirements of 5.4.

5.5.2 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.4.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.6 Machinery seating

5.6.1 The general requirements for machinery seating are given in Pt 3, Ch 2,6.9.

5.6.2 Main and auxiliary engines are to be effectively secured to the hull structure by seatings of adequate scantlings to resist the gravitational thrust, torque and vibration forces which may be imposed upon them.

5.6.3 The longitudinal girders forming the engine seating are to extend as far forward and aft as is practicable and are to be adequately supported by transverse floors or brackets.

5.6.4 Where stiffening is of plate construction, engine holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, bracket floors are to be fitted.

5.6.5 Machinery seatings are to be attached by means of primary bonding angles in accordance with 1.18.

5.7 Drainage arrangements

5.7.1 Suitable arrangements are to be made to provide free passage of air from all parts of the tanks to the air pipes, *see also* Pt 9, Ch 1,5.

5.7.2 Sufficient limber holes are to be positioned in the internal bottom structure to allow for the drainage of water from all parts of the bilge to the pump suctions.

5.7.3 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations. *See* LR's *Guidance Notes for Calculation Procedures for Composite Construction*.

5.7.4 Openings in the webs of stiffening sections, baffle plates, etc., are, in general, to be formed by moulded-in preforms under top hat type stiffening. Edges of openings in plate laminates are to be suitably sealed in accordance with 1.29.

5.8 Rudder horns

5.8.1 The scantlings of the rudder horn will be specially considered and in the case of high aspect ratio or novel designs direct calculations will be required to be submitted in accordance with Pt 3, Ch 1,2.

5.9 Sternframes

5.9.1 Where it is proposed to mould a composite sternframe, the scantlings and arrangements will be specially considered on the basis of direct calculations and loadings submitted by the Builders and designers.

5.10 Skeg construction

5.10.1 Skegs are to be effectively integrated into the adjacent structure and their design is to be such as to facilitate this, *see also* 3.9.

5.10.2 The scantlings of skegs and the internal diaphragms at bulkheads and web frames are to be sufficient to withstand any docking forces to which they may be subjected.

5.11 Forefoot and stem

5.11.1 For craft of composite sandwich construction the forefoot region is to be so designed that in the event of local impact (*see also* 2.8) with floating debris, the resultant damage will be limited. This may be achieved by:

(a) Arranging the individual plies of the laminate such that any delamination will be directed to the outer surface of the laminate, *see* Fig. 3.5.1.
(b) The addition of a 'sacrificial nose', *see* Fig. 3.5.2.
(c) By the addition of suitable sheathing, in accordance with 2.9.
(d) For vessels where the operating high speed waterline results in the exposure of the forefoot region, the laminate sequence in the keel area will be specially considered.

5.12 Transom knee

5.12.1 Centre and side girders are to be bracketed to the transom framing members by means of substantial knees. The face flat area of the girders may be gradually reduced to that of the transom stiffening member in accordance with Fig. 3.5.3.

5.12.2 Hard spots are to be avoided in way of the end connection, and care taken to ensure that the stiffening member to which the transom knee is bracketed can satisfactorily carry the transmitted bending moment.

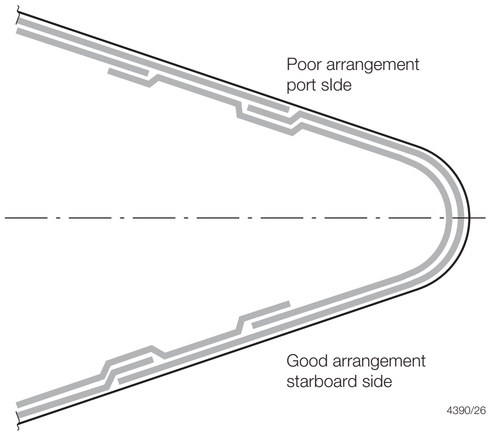


Fig. 3.5.1
Arrangement of laminate in way of forefoot and stem

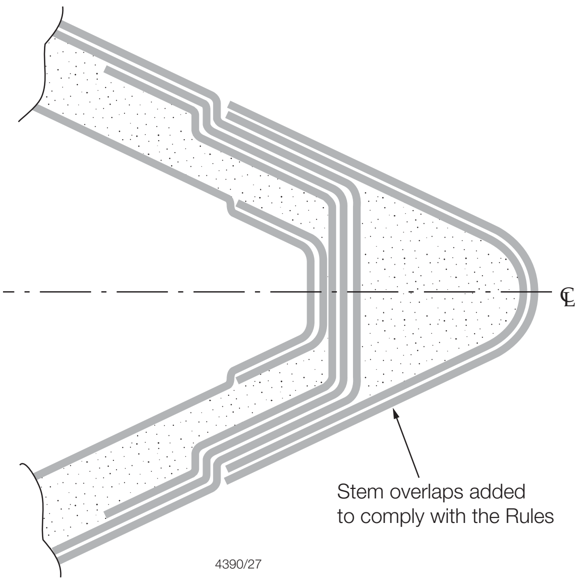


Fig. 3.5.2 'Sacrificial nose'

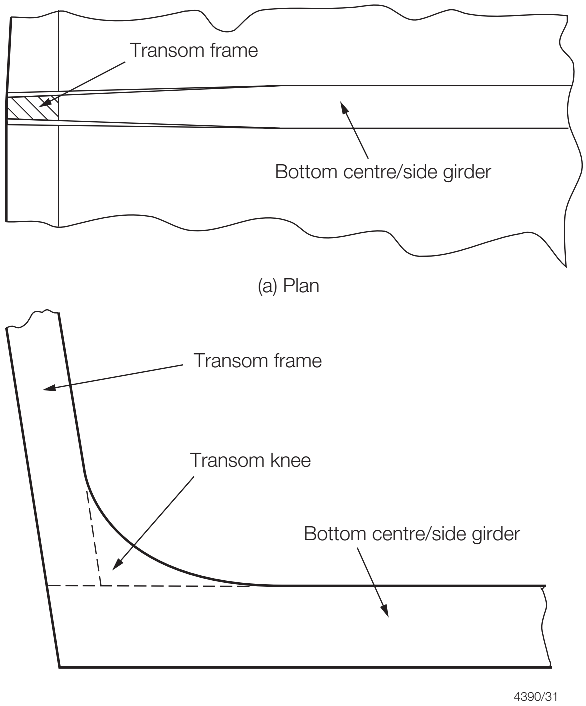


Fig. 3.5.3 Transom knee

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 The requirements given in this Section provide for double bottom construction of mono-hull craft in association with either transverse or longitudinal framing.

6.1.2 Where required in accordance with Pt 3, Ch 2,6, double bottoms are generally to extend from the collision bulkhead to the after peak bulkhead, as far as this is practicable taking into account the design and proper working of the craft. In addition, the inner bottom is to be continued to the craft's side in such a manner as to protect the bottom to the turn of bilge or chine.

6.1.3 The double bottom structure in way of girders and duct keels is to be sufficient to withstand the forces imposed by dry-docking the craft.

6.1.4 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuity. Where girders are cut at bulkheads, their longitudinal strength is to be maintained.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of the craft. The web thickness, t_w, of a centreline girder of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5 mm:

$$t_w = \sqrt{k_A}\left(\frac{L_R}{8} + 3{,}64\right) \geq 5 \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.3.2 The web thickness of a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centre girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge does not exceed 6,0 m, side girders are not required.

6.4.2 Where the breadth of the floor at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are, in general, to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by 1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(0{,}064L_R + 4{,}32\right) \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.4.5 The face area and face thickness of side girders are to comply with the requirements for plate floors as defined in 5.4.7 and 5.4.8 respectively.

6.4.6 Additionally, the requirements of 4.5 for bottom longitudinal primary stiffeners are to be complied with.

6.5 Bracket floors

6.5.1 Between plate floors, the shell inner bottom plating is to be supported by bracket floors. The brackets are to have the same thickness as plate floors and, where they are of single skin laminate construction, are to be stiffened on the unsupported edge.

6.5.2 In longitudinally framed craft, the brackets are to extend from the centre or side girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket to be taken less than 3/4 of the depth of centre girder. Brackets are to be fitted at every web frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

6.5.3 In transversely framed craft, the breadth of the brackets attaching the bottom and inner bottom frames to the centre girder and margin plate is to be not less than 3/4 of the depth of the centre girder.

6.6 Plate floors

6.6.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction.

6.6.2 The web thickness, t_w, for non-watertight plate floors of 'top-hat' type section is to be not less than as required by 1.16 or as determined as follows, whichever is the greater and in no case is t_w to be taken less than 5,0 mm.

$$t_w = \sqrt{k_A}\left(0{,}064L_R + 4{,}32\right) \text{ mm}$$

where

k_A and L_R are as defined in 1.5.1.

6.6.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.6.2.

6.6.4 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

6.6.5 Additionally, the requirements of 4.8 for bottom transverse web frames are to be complied with.

6.6.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

6.7 Watertight floors

6.7.1 The scantlings of watertight floors are to comply with the requirements for plate floors as detailed in 6.6.

6.7.2 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively.

6.8 Tankside brackets

6.8.1 The scantlings of tankside brackets are to comply with the requirements for plate floors as detailed in 6.6.

6.9 Inner bottom laminate

6.9.1 Inner bottom laminates forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deep tanks as detailed in 7.3 or 7.4 respectively and, where forming vehicle, passenger or other decks the requirements of Section 8 are to be complied with.

6.9.2 The bending moment assumed to be carried by the inner bottom plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 6.9.3 and 6.9.5 respectively.

6.9.3 An estimate of the thickness of the **inner bottom single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.4 In no case is the minimum thickness of single skin plating to be taken as less than 5 mm.

6.9.5 An estimate of the stiffness EI, the thickness of single skin plating for **outer and inner skins of the bottom sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

6.9.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1, *see* 2.3.1.

6.9.7 Special consideration may be given to laminate thicknesses lesser than that required by 6.9.4 and 6.9.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is to be demonstrated as required by 2.8.2.

6.10 Inner bottom longitudinals

6.10.1 The inner bottom longitudinals are to be supported by inner bottom transverse web frames, floors, bulkheads, or other primary structures, generally spaced not more than 2 m apart.

6.10.2 Inner bottom longitudinals are to be continuous through the supporting structures.

6.10.3 Where it is impracticable to comply with the requirements of 6.10.2, or where it is desired to terminate the inner bottom longitudinals in way of bulkheads or integral tank boundaries, the longitudinals are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets.

6.10.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b).

6.10.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.11 Inner bottom transverse web framing

6.11.1 Inner bottom transverse web frames are defined as primary stiffening members which support inner bottom longitudinals. They are to be continuous and substantially bracketed at their end connections to bottom web frames, bottom floors and tankside brackets.

6.11.2 Where it is impracticable to comply with the requirements of 6.11.1, or where it is desired to terminate the inner bottom transverse web frames in way of centre or side girders, bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular attention is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

6.11.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

6.11.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

6.12 Margin plates

6.12.1 A margin plate, if fitted, is to have a thickness as required for the inner bottom plating.

6.13 Wells

6.13.1 Small wells constructed in the double bottom are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the craft. Other well arrangements (e.g. for lubricating oil under main engines) may be considered provided they give protection equivalent to that afforded by the double bottom.

6.14 Transmission of pillar loads

6.14.1 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

6.15 Drainage arrangements

6.15.1 Suitable arrangements are to be made to provide free passage of air and water from all parts of the tanks to the air pipes and pump suctions.

6.15.2 Particular attention is to be given to the positioning of limbers to ensure adequate drainage and to avoid stress concentrations, *see also* 5.7.

6.15.3 Openings in the webs of stiffening sections, baffle plates, etc., are to be suitably sealed in accordance with 4.16.

6.16 Manholes

6.16.1 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to and ventilation of all parts of the double bottom. The size of the manhole openings in plate laminates is not, in general, to exceed 50 per cent of the double bottom depth unless edge reinforcement is provided. Holes are, in general, not to be cut in the centre girder, except in tanks at the forward and after ends of the craft, and elsewhere where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

6.17 Pressure testing

6.17.1 Double bottoms are to be tested upon completion with a head of water representing the maximum internal pressure which could be experienced in service, but not less than a head of water equivalent to the level of the upper deck.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 The requirements of this Section apply to craft with bulkheads of either sandwich or single skin composite construction.

7.1.2 Watertight and collision bulkheads are to be fitted in accordance with the requirements of Pt 3, Ch 2,4.

7.1.3 FRP composite bulkheads and plywood bulkheads are, where practicable, to be suitably attached to receiving frames, *see also* LR's *Guidance Notes for Structural Details*. The bulkheads are to be attached using double angles or equivalent, *see* 1.18. Proposals to fit bulkheads and tank boundaries on receiving strips in lieu of frames, will be individually considered.

7.1.4 Where bulkheads are of steel or aluminium construction, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. The method of attachment to the framing will be specially considered.

7.1.5 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations which are to be submitted with the plans.

7.1.6 In deep tanks which extend from side to side a centreline bulkhead is generally to be fitted. The bulkhead may be intact or perforated as desired. If intact the scantlings are to comply with the requirements of 7.4 and 7.11 for tank boundary bulkheads. If perforated, they are to comply with the requirements of 7.11 for washplates.

7.1.7 The scantlings of non-watertight or partial bulkheads are, in general, to be as required by 7.3 for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames, in the same position, as appropriate.

7.2 Symbols and definitions

7.2.1 The symbols and definitions for use within this Section are as given in 1.5.1.

7.3 Watertight bulkheads

7.3.1 Composite watertight bulkheads may be of sandwich construction, with or without stiffeners, or of single skin construction with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Sandwich timber bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.3.2 The bending moment assumed to be carried by the watertight bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.3.3 and 7.3.5 respectively.

7.3.3 An estimate of the thickness of watertight **bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

7.3.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bulkhead sandwich panel** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.3.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

7.3.7 Special consideration may be given to laminate thicknesses lesser than that required by 7.3.4 and 7.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.3.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the bulkhead stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the appropriate load model.

7.3.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.3.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.3.11 Bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.3.12 Bulkheads in engine rooms that may be exposed to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.4 Deep tanks

7.4.1 Composite integral/deep tank bulkheads may be of sandwich construction with or without stiffeners, or of single skin with closely spaced vertical or horizontal stiffeners. Where steel or aluminium alloy integral/deep tank bulkheads are fitted, their scantlings and arrangements are to be in accordance with Pt 6, Ch 3 or Pt 7, Ch 3 respectively. Other forms of bulkhead construction will be considered on the basis of equivalent strength and stiffness. Where bulkheads are of novel design they will be specially considered.

7.4.2 The bending moment, M_b or M_c, as appropriate, assumed to be carried by the integral/deep tank bulkhead plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 7.4.3 and 7.4.5 respectively.

7.4.3 An estimate of the thickness of **integral/deep tank bulkhead single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.4 In no case is the minimum thickness of single skin plating to be taken as less than 4,5 mm.

7.4.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of **integral/deep tank bulkhead sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

7.4.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1, *see* 2.6.2.

7.4.7 Special consideration may be given to laminate thicknesses less than that required by 7.4.4 and 7.4.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

7.4.8 The Rule requirements for bending moment, shear force, shear stress and deflection for the integral/deep tank stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 for both non-displacement or displacement type craft, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

7.4.9 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

7.4.10 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7.

7.4.11 Integral/deep tank bulkheads are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.4.12 Integral/deep tank bulkheads in engine rooms that may be subjected to fuel oils are to be suitably protected against damage by fuel oil and by fire, *see* 7.15.

7.5 Double bottom tanks

7.5.1 The scantlings of double bottom tanks are to meet the structural requirements for deep tanks in accordance with 7.4.

7.5.2 Where the crown of a double bottom tank forms a vehicle, passenger or other deck, the requirements of Section 8 are also to be complied with.

7.6 Collision bulkheads

7.6.1 The scantlings of composite collision bulkheads are to meet the requirements of 7.3 but with allowable tensile, compressive and shear stress limits for collision bulkheads as indicated in Table 7.3.1 in Chapter 7.

7.6.2 If the collision bulkhead forms the boundary of a deep tank or cofferdam the requirements of 7.4 are to be complied with.

7.7 Gastight bulkheads

7.7.1 Where gastight bulkheads are fitted, in accordance with Pt 3, Ch 2,4, their scantlings are to be as required for watertight bulkheads.

7.7.2 Gastight bulkheads are to be fitted to protect accommodation spaces from gases and vapour fumes from machinery, exhaust and fuel systems.

7.8 Plywood bulkheads

7.8.1 Plywood used for bulkheads is to be high quality marine plywood, and is to be in accordance with the requirements of Ch 2,2.17.

7.8.2 The structural requirements of plywood watertight bulkheads are to be as required by 7.1.

7.9 Non-watertight or partial bulkheads

7.9.1 Where a bulkhead is structural but non-watertight, the scantlings are, in general, to be as required for watertight bulkheads or equivalent in strength to web frames in the same position. Partial bulkheads that are non-structural are outside the scope of LR classification.

7.10 Stiffeners passing through bulkheads

7.10.1 Primary longitudinal stiffening members are to be continuous through transverse bulkheads.

7.10.2 Where a stiffener passes through a watertight bulkhead the bonding of the stiffener and compensation in way is to be not less than the laminate weight of the bulkhead.

7.10.3 Where structural members pass through the boundaries of watertight bulkheads or integral/deep tanks, and leakage into the adjacent space could be hazardous or undesirable, suitable cofferdams are to be built into the cores of top-hat stiffeners on each side of the boundary. The minimum thickness of such cofferdams is 4,5 mm.

7.10.4 Pipe or cable runs through watertight bulkheads are to be fitted with suitable watertight glands.

7.11 Wash plates

7.11.1 Tanks are to be subdivided as necessary by internal baffles or wash plates and the minimum thickness of the laminate for any internal structure is not, in general, to be less than 4,5 mm at a fibre content of 0,5 or equivalent thickness. Baffles or wash plates which support hull framing are to have scantlings equivalent to web frames in the same position.

7.11.2 Wash plates and wash bulkheads are, in general, to have an area of perforation not less than 10 per cent of the total area of the bulkhead. The perforations are to be so arranged that the efficiency of the bulkhead as a support is not impaired.

7.11.3 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

7.12 Cofferdams

7.12.1 A cofferdam is to be fitted between fresh water and oil fuel or sanitary tanks. The scantlings of cofferdams are to comply with the requirements for deep tank bulkheads given in 7.4.

7.13 Coatings

7.13.1 Fuel tanks are to incorporate a resin rich surface or be coated with an oil retardant resin on the internal exposed surfaces. Potable fresh water tanks are similarly to be coated with a suitable non-tainting resin.

7.14 Air pipes

7.14.1 Air pipes sufficient in number and area are to be fitted to each tank in accordance with Pt 15, Ch 2,11.

7.15 Fire protection

7.15.1 Fire protection requirements as given in Part 17 are to be complied with.

7.16 Access

7.16.1 All compartments within the craft are to be accessible in order to facilitate proper maintenance and future structural surveys. Linings on craft-sides, deck-heads and bulkheads etc., must be capable of being removed. Similarly, sufficient space must be available below lower decks/soles to provide proper access to the bottom structure; an adequate number of manholes, removable panels, etc., are to be provided for this purpose.

7.16.2 Doors fitted through watertight bulkheads are to be of equivalent construction to the bulkhead in which they are fitted, permanently attached, capable of being closed watertight from both sides of the bulkhead and are to be tested watertight.

7.16.3 Doors or hatches are not to be fitted in collision bulkheads, except in craft of less than 21 m Rule length, L_R, or where it would be impracticable to arrange access to the forepeak other than through the collision bulkhead. Where fitted, such doors or hatches are to be watertight, as small as practicable and are to open into the forepeak compartment. Consideration will be given to operation from one side only. Doors or hatches in collision bulkheads are to be kept closed at all times while the craft is at sea.

7.16.4 Particular attention is to be given to the design and workmanship of adequate access manholes in tanks.

7.16.5 Where a manhole is fitted in a tank, the exposed edges of all openings cut in sandwich panels are to be suitably sealed. In general a high density foam core (or equivalent material) is to be used around the perimeter of such openings. Exposed edges in way of cut-outs in sandwich panels are to be overlaminated with a weight of laminate not less than that required for the skin of the sandwich panel exposed to the fluid or as required by 2.5.1, whichever is the greater, *see* 2.3.1.

7.16.6 Manhole covers are to be attached using bolts/studs spaced at not greater than six diameters. The cover is to be fitted on a suitable seal. Where studs or bolts used to attach the cover plate to the manhole pass through the laminate, they are to be suitably secured, sealed and over-laminated.

7.17 Testing

7.17.1 Integral/deep tanks are to be tested by air pressure or by a head of water. If tested by water, the head is to be either to 1,8 m above the crown of the tank or to the top of the air or overflow pipe, whichever is the greater. When tested by air, the pressure is not to exceed 0,014 N/mm^2. The head to which the tank will be subjected in service is to be indicated on the plans submitted.

■ *Section 8* Deck structures

8.1 General

8.1.1 The deck structure may be of either single skin or sandwich construction and is to be supported by transverse beams with fore and aft girders or by longitudinals with deep transverse beams.

8.1.2 Beams are to be fitted at each frame position and be bracketed to the side frames. Strong beams and deep transverse beams are to align with and be effectively connected to the side web frames. They are also to be fitted at the ends of large openings in the deck.

8.1.3 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Deck structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

8.1.7 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.8 Tripping brackets are to be fitted on deep webs.

8.2 Symbols and definitions

8.2.1 The symbols defined in 1.5.1 apply, unless otherwise specified.

8.3 Strength/weather deck laminate

8.3.1 The bending moment assumed to be carried by the strength/weather deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.3.2 and 8.3.4 respectively.

8.3.2 An estimate of the thickness of **strength/weather deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.3.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

8.3.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.3.3 and 8.3.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.3.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.3.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.3.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* 2.9.

8.4 Lower deck/inside deckhouse deck laminate

8.4.1 The bending moment assumed to be carried by the lower deck/inside deckhouse deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of the **lower deck/ inside deckhouse deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3 mm.

8.4.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **lower deck/inside deckhouse deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

8.4.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with.

8.5 Accommodation deck laminate

8.5.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.4.

8.5.2 Sandwich timber, plywood or other forms of deck construction will be considered on the basis of equivalent strength and stiffness.

8.6 Cargo deck laminate

8.6.1 The bending moment assumed to be carried by the cargo deck plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.6.2 and 8.6.4 respectively.

8.6.2 An estimate of the thickness of the **cargo deck single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 4 mm.

8.6.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **cargo deck sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.6.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

8.6.6 Special consideration may be given to laminate thicknesses lesser than that required by 8.6.3 and 8.6.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* 2.3.1, and the equivalent impact resistance is demonstrated as required by 2.8.2.

8.7 Decks forming crown of tanks

8.7.1 Decks forming the crowns of tanks are to comply with the requirements for the appropriate deck and, are to be additionally examined for compliance with the requirements for deep tanks given in 7.4.

8.8 Strength/weather deck stiffening

8.8.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

8.8.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **strength/weather deck secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.8.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.8.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.9 Lower deck/inside deckhouse stiffening

8.9.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the lower deck/inside deckhouse stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.9.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.9.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.10 Accommodation deck stiffening

8.10.1 Accommodation decks are, in general, to be treated as lower deck/inside deckhouse decks, with their scantling requirements determined in accordance with 8.9.

8.11 Cargo decks

8.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for cargo deck stiffeners are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the appropriate load model. Primary members are assumed to be load model (a), secondary members are, in general, assumed to be load model (b), however special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided. Additionally where the cargo comprises wheeled vehicles the requirements of Ch 5,3 are to be complied with.

8.11.2 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.11.3 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

8.12 Deck openings

8.12.1 All openings are to be supported by an adequate framing system, pillars or cantilevers. When cantilevers are used, stiffening requirements may be derived from direct calculations.

8.12.2 Where stiffening members are stopped in way of an opening, they are to be attached to carlings, girders, transverses or coamings.

8.12.3 The corners of large hatchways in the strength/weather deck within 0,5*L* amidships are to be elliptical, parabolic or rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.4 Where elliptical corners are arranged, the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than two to one, nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in Fig. 3.8.1. Where parabolic corners are arranged, the dimensions are also to be as shown in Fig. 3.8.1.

8.12.5 Where the corners are parabolic or elliptical, increased thickness of laminate will, in general, not be required.

8.12.6 For other shapes of corner, reinforcement of the size and extent shown in Fig. 3.8.2 will, in general, be required. The required weight of reinforcement is to be not less than 25 per cent greater than the adjacent deck laminate.

8.12.7 For lower decks the corners of large openings are to be rounded, with a radius generally not less than 1/24 of the breadth of the opening.

8.12.8 Reinforcement as given in 8.12.6 will be required at lower decks in way of rapid change in hull form to compensate for loss of deck cross-sectional area. Otherwise, reinforcement will not normally be required.

8.12.9 Adequate transverse strength is to be provided in the deck area between large hatch openings subjected to transverse and buckling loads.

8.12.10 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

8.13 Sheathing

8.13.1 The requirements for deck sheathing are given in 2.9.

8.14 Novel features

8.14.1 Novel features will be specially considered in accordance with 2.7.

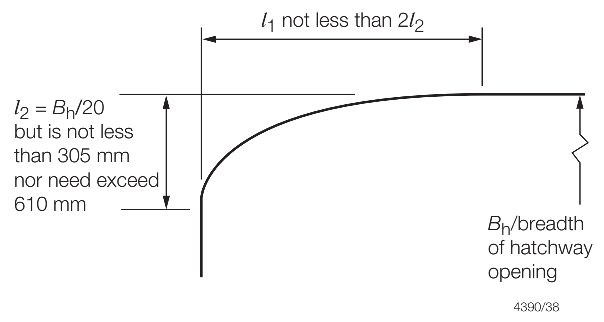


Fig. 3.8.1 Hatch opening geometry

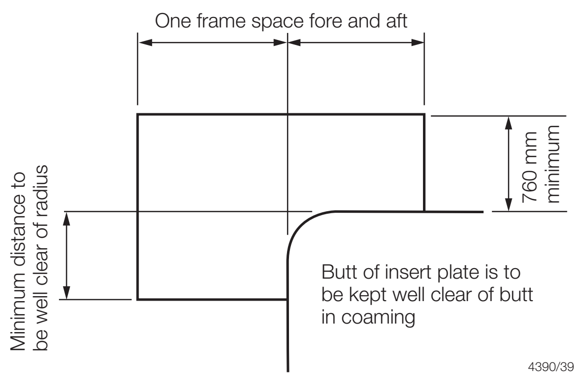


Fig. 3.8.2
Reinforcement in way of hatch opening

8.14.2 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

Section 9
Superstructures, deckhouses and bulwarks

9.1 General

9.1.1 Superstructures, deckhouses and bulwarks may be of single skin or sandwich construction or a combination of both.

9.1.2 Where practicable, superstructures and deck-houses are to be designed with well cambered decks and well radiused corners to build rigidity into the structure.

9.1.3 The laminate and supporting structure are to be suitably reinforced in way of stressed corners of openings, cranes, masts, derrick posts, machinery, fittings and other heavy or vibrating loads.

9.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

9.1.5 Secondary stiffening members are, in general, to be continuous through supporting structures.

9.1.6 Structures subject to concentrated loads, such as pillars out of line, are to be suitably reinforced. Where concentrations of loading on one side of a stiffener may occur, the stiffener is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

9.1.7 Structures are to comply with the minimum thickness requirements of Section 2.

9.1.8 Where a superstructure is fitted, the side shell plating, in way of the end of the superstructure, may be required to be increased in thickness, *see* 3.14.

9.2 Symbols and definitions

9.2.1 The term 'house' is used in this Section to include both superstructures and deckhouses.

9.2.2 The symbols for use within this Section are as defined in 1.5.1 unless otherwise specified.

9.3 House side laminates

9.3.1 The bending moment assumed to be carried by the house side plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.3.2 and 9.3.4 respectively.

9.3.2 An estimate of the thickness of **house side single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.3.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **house side sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.3.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.4 House front laminates

9.4.1 The bending moment assumed to be carried by the house front plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.4.2 and 9.4.4 respectively.

9.4.2 An estimate of the thickness of **house front single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.4.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house front sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.5 House aft end laminates

9.5.1 The bending moment assumed to be carried by the house aft end plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.5.2 and 9.5.4 respectively.

9.5.2 An estimate of the thickness of **house aft end single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.5.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house aft end sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.5.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.6 House top laminates

9.6.1 The bending moment assumed to be carried by the house top plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.6.3 and 9.6.5 respectively.

9.6.2 An estimate of the thickness of **house top single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.6.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **house top sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.6.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.7 Coachroof laminates

9.7.1 The bending moment assumed to be carried by the coachroof plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.7.2 and 9.7.4 respectively.

9.7.2 An estimate of the thickness of **coachroof single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.3 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.7.4 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **coachroof sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.7.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.8 Machinery casing laminates

9.8.1 The bending moment assumed to be carried by the machinery casing plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.8.2 and 9.8.4 respectively.

9.8.2 An estimate of the thickness of the **machinery casing single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits are indicated in Table 7.3.1 in Chapter 7 for house side plating.

9.8.3 In no case is the minimum thickness of single skin plating to be taken as less than 3,0 mm.

9.8.4 An estimate of the stiffness EI, the thickness of single skin plating for outer and inner skins of the **machinery casing sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.8.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.9 Forecastle requirements

9.9.1 The side laminate may be a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. The laminate is to be the same weight as the side hull laminate at the deck edge position, and is to be increased along the connection, if fitted, to the top edge of the hull. Suitable scarfing arrangements are to be made to ensure the continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. The laminate is to be stiffened by sideframes carried up or they may be stopped short of the deck provided the ends are effectively built-in. Deep webs are to be fitted to ensure overall rigidity of the side laminate.

9.10 House side stiffeners

9.10.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.10.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house side secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.10.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.10.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.11 House front stiffeners

9.11.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.11.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house front secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.11.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.11.4 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.12 House aft end stiffeners

9.12.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.12.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house aft end secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.12.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.12.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.13 House top stiffeners

9.13.1 The house top is to be efficiently supported by a system of transverse or longitudinal beams and girders. The span of the beams is generally not to exceed 2,4 m and the beams are to be effectively built into the house upper coamings and girders.

9.13.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.13.3 The Rule requirements for bending moment, shear force, shear stress and deflection for the **house top secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.13.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.13.5 The geometric properties of stiffeners sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.14 Coachroof stiffeners

9.14.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **coachroof primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.14.2 The Rule requirements for the bending moment, shear force, shear stress and deflection for the **coachroof secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.14.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.15 Machinery casing stiffeners

9.15.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **machinery casing secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.15.4 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if found necessary. Particular attention is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

9.15.5 Where casing stiffeners carry loads from deck transverses, girders, etc., or where they are in line with pillars below, they are to be suitably reinforced.

9.15.6 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.16 Forecastle stiffeners

9.16.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle primary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (a).

9.16.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the **forecastle secondary stiffeners** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

9.16.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.16.4 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.17 Superstructures formed by extending side structure

9.17.1 Superstructure first tier sides formed by extending the hull side structure are to be in accordance with the requirements for house fronts indicated in 9.4 and 9.11 for laminates and stiffeners respectively, but need not be taken as greater than the side structure requirements at the deck edge at the same longitudinal position.

9.18 Fire aspects

9.18.1 Fire detection, protection and extinction requirements are given in Part 17.

9.19 Openings

9.19.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities. Continuous coamings or girders are to be fitted below and above doors and similar openings.

9.19.2 Particular attention is to be paid to the effectiveness of end bulkheads when large openings for doors and windows are fitted, and also to the upper deck stiffening in way.

9.19.3 Special care is to be taken to minimise the size and number of openings in the side bulkheads in the region of the ends of houses within $0{,}5L_R$ amidships. Account is to be taken of the high vertical shear loading which may occur in these areas.

9.19.4 The requirements for closing arrangements and outfit are given in Pt 3, Ch 4.

9.20 Mullions

9.20.1 Window openings are to be suitably framed and mullions will in general be required.

9.20.2 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

9.20.3 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as indicated in 1.7, in no case is the width of effective plating to be taken greater than the distance between adjacent window openings.

9.20.4 Where significant shear forces are to be transmitted by window frames, adequate shear rigidity requires to be verified.

9.21 Global strength

9.21.1 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular attention is to be paid when a superimposed tier is wider than its supporting tier and when significant loads are carried on the house top.

9.21.2 Where practicable, web frames are to be arranged in line with bulkheads below.

9.21.3 Internal bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

9.22 House/deck connection

9.22.1 Adequate support under the ends of houses is to be provided in the form of webs, pillars, diaphragms or bulkheads in conjunction with reinforced deck beams.

9.22.2 Special attention is to be given to the connection of the house to the deck in order to provide an adequate load distribution and avoid stress concentrations.

9.22.3 Typical design details of house/deck connections are given in LR's *Guidance Notes for Structural Details*.

9.23 Sheathing

9.23.1 Sheathing arrangements are to comply with 2.9.

9.24 Novel features

9.24.1 Laminate and stiffener requirements may need to be determined by direct calculation where the house is of unusual design, form or proportions, *see also* 2.7.

9.25 Bulwarks

9.25.1 General requirements for bulwarks are given in Pt 3, Ch 4.8.

9.25.2 The bending moment assumed to be carried by the bulwark plating is to be not less than that determined from 1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 9.25.3 and 9.25.5 respectively.

9.25.3 An estimate of the thickness of the **bulwark single skin plating** is to be determined from 1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.12.3 and 1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.4 In no case is the minimum thickness of single skin plating to be taken as less than 2,5 mm.

9.25.5 An estimate of the stiffness EI, thickness of single skin plating for outer and inner skins of the **bulwark sandwich panels** and the thickness of core material is to be determined from 1.13.2 and 1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using 1.13.7 and 1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

9.25.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.5.1.

9.25.7 The Rule requirements for bending moment, shear force, shear stress and deflection for the **bulwark stays** are to be determined from the general equations given in 1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 for the load model (d).

9.25.8 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

9.25.9 The geometric properties of stiffener sections are to be calculated in accordance with 1.15 using an effective width of attached plating as given in 1.7.

9.25.10 Bulwarks should not be cut for gangway or other openings near the breaks of houses.

9.25.11 Attention is to be paid to avoid discontinuity of strength of the bulwark, particularly in way of local increases in stress and changes in height.

9.25.12 **Fishing craft** are to have bulwarks fitted. The bulwark may be formed as a continuation of the hull laminate, an integral part of the deck moulding or connected as a separate assembly. Where the bulwark is considered to be stressed and contributing to the global strength of the craft, the laminate weight of the bulwark is not to be less than the sheer laminate weight. In no case is the bulwark laminate weight to be taken as less than 80 per cent of the shell weight. The bulwark is to be supported by suitable stiffening which may be formed by a continuation of the side frames, or by top hat, or plate laminate stays of the same weight as the bulwark. These frames are not generally to be spaced more than two side frame spacings apart.

9.25.13 In way of gantries, trawl gallows, mooring pipes etc. the laminate in way is to be increased by 50 per cent.

9.25.14 **Pilot craft** are to be fitted with a suitable hand rail system adjacent to the exposed areas of the working decks and platforms and in addition these areas should have non skid surfaces. Where permitted by the Flag Administration, a suitable approved continuous safety rail system will be acceptable. Suitable operating procedures are to be in place for the trained crew.

9.26 Freeing arrangements

9.26.1 The requirements for freeing arrangements are given in Pt 3, Ch 4,9.

9.27 Free flow area

9.27.1 The requirements for free flow area are given in Pt 3, Ch 4,9.3.

9.28 Guard rails

9.28.1 The requirements for guard rails are given in Pt 3, Ch 4,8.4.

Section 10
Pillars and pillar bulkheads

10.1 General

10.1.1 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are to be constructed out of materials of adequate compressive strength and modulus, usually steel or aluminium and these are generally to be of solid, tubular or I beam form. A pillar may be a fabricated trunk or partial bulkhead.

10.2 Symbols and definitions

10.2.1 The symbols for use within this Section are as defined in 1.5.1, unless otherwise specified in the appropriate sub-Section.

10.3 Determination of spans

10.3.1 The effective span length of pillar, l_{ep}, is in general the distance between the head and heel of pillar. Where substantial brackets are fitted, the effective length of pillar, l_{ep}, may be reduced by 2/3 of the depth of the brackets at each end.

10.4 Head and heel connection

10.4.1 The structure in way of head and heel connections is to be suitably reinforced. The webs and face reinforcement of such supporting structure are to be locally increased as necessary with due account being taken of both the compression and bending moment in way.

10.4.2 Pillars are to be attached at their heads and heels to plates supported by efficient brackets. Where the attachment is through bolted, suitable inserts or compression tubes are to be incorporated within the deck and hull framing to prevent over-compression and damage to the laminate in way. Alternatively, tapping plates may be incorporated within the face reinforcement of the stiffener. Details of the proposed arrangement are to be indicated on the submitted plans.

10.5 Alignment and arrangement

10.5.1 Pillars are to be fitted on main structural members. They should be fitted below deckhouses, windlasses,winches, capstans and elsewhere where considered necessary.

10.5.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

10.5.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

10.6 Minimum thickness

10.6.1 The minimum wall thickness of steel or aluminium pillars are to be as required by Pt 6, Ch 3 or Pt 7, Ch 3 respectively.

10.6.2 The minimum wall thickness of FRP pillars will be specially considered.

10.7 Pillar scantlings

10.7.1 The scantlings of steel or aluminium pillars, and pillar bulkheads, are to be as required by Pt 6, Ch 3 and Pt 7, Ch 3 respectively.

10.7.2 The scantlings of FRP pillars/pillar bulkheads are to be in accordance with 10.10.

10.7.3 Where a pillar is of unusual material, the scantlings will be specially considered.

10.8 Pillars in tanks

10.8.1 Pillars are in no circumstances to pass through tanks. Where loads are to be transmitted through the tank, pillars within the tanks are to be carefully aligned with the external pillars.

10.8.2 Pillars within tanks are, in general, to be of solid cross section. Proposals to use hollow section or tubular pillars will be subject to special consideration and the scantlings as determined from the Rules may be required to be increased dependent upon the material to be used, the fluid contained and the arrangement of the pillars. Hollow pillars are to be adequately drained and vented.

10.8.3 Pillars within tanks which may be subjected to tensile stresses due to hydrostatic pressure, are to be designed to provide sufficient connection to withstand the tension load imposed.

10.9 Pillar bulkheads

10.9.1 Where the pillar bulkhead is of steel or aluminium construction the method of attachment to the surrounding structure/framing will be specially considered.

10.9.2 Where a pillar bulkhead supports a concentrated load the structure in way is to be suitably reinforced to distribute the load into the adjacent stiffening.

10.10 Composite pillars and pillar bulkhead scantlings

10.10.1 The load P_p, assumed to be carried by a pillar is to be determined from:

$$P_p = S_{gt} \, b_{gt} \, P_c + P_a \quad \text{kN}$$

where

P_p = design load supported by the pillar, which is to be taken as not less than 5 kN
P_c = basic deck girder design pressure as appropriate, plus any other loadings above the pillar, in kN/m^2
P_a = load, in kN, from pillar or pillars above, assumed zero if there are no pillars over
S_{gt} = spacing, or mean spacing, of girders or transverses, in metres
b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillars, in metres.

10.10.2 The load P_b, assumed to be carried by a pillar bulkhead is to be determined from:

$$P_{pb} = S_{bs}\, b_{pb}\, P_c + P_a \quad \text{kN}$$

where

P_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead, in kN
P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2
S_{bs} = spacing, or mean spacing of bulkheads or effective transverses/longitudinal stiffeners, in metres
b_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffener at the top of the bulkhead effectively distributes the load evenly into the stiffeners.

10.10.3 The slenderness ratio (l_{ep}/r) of a pillar or plate stiffener combination is to be determined from:

$$r = \sqrt{\frac{\Sigma\,(E_i\, I_i)}{\Sigma\,(E_i\, A_i)}} \quad \text{cm}$$

where

r = least radius of gyration of pillar cross section, in cm
l_{ep} = effective length of pillar, in cm
E_i, I_i and A_i are as defined in 1.5.1.

Table 3.10.1 Pillar location factors

Location	f_p
Supporting weatherdeck	0,50
Supporting vehicle deck	0,25
Supporting passenger deck	0,50
Supporting lower/inner deck	0,75
Supporting coachroof	0,75
Supporting deckhouse top	1,00

10.10.4 The compressive loads P_p or P_{pb}, from 10.10.1 and 10.10.2 for pillars and pillar bulkheads respectively are not to exceed a function of the critical load P_{cr}, determined from 10.10.5:

$$P_p \text{ (or } P_{pb}) < f_p\, P_{cr} \quad \text{kN}$$

where

f_p is a factor dependent upon location and is as indicated in Table 3.10.1.

10.10.5 The critical compressive load, P_{cr}, for pillars and plate/stiffener combinations with a slenderness ratio (l_e/r) between 75 and 110 may be determined from:

$$P_{cr} = \frac{k\,\pi^2\,\Sigma\,(E_{ci}\, I_i)}{l_{ep}^{\,2}} \times 10^5 \quad \text{kN}$$

where

l_{ep} = effective span length of pillar or stiffener plate combination, in metres
E_{ci} = compressive modulus of plate laminate, in N/mm^2
k = end fixity factor
= 1,5 for full fixed/bracketed
= 0,75 for partially fixed
= 0,5 for free ended

Where the proposed slenderness ratio is below 75 the pillar will be specially considered. Slenderness ratios in excess of 110 are not to be contemplated.

10.10.6 The stiffener/plate combination used to determine the scantlings for pillar bulkheads is to be that of a stiffener with an effective width of attached plating carrying a load as determined from 1.7.

10.10.7 The scantlings of wooden pillar bulkheads will be specially considered on the basis of the Rules. Such pillar bulkheads are to be of equivalent strength, stiffness and load carrying capability.

10.11 Detail in way of sandwich structure

10.11.1 The attachment of pillars to sandwich structures should, in general, be through an area of single skin laminate, *see* Ch 2,4.3. Where this is not practicable and the attachment of the pillar has to be by bolting through a sandwich structure then a wood, or other suitable solid insert is to be fitted in the core in way.

10.12 Fire aspects

10.12.1 Pillars are to be suitably protected against fire, where necessary, be self extinguishing or be capable of resisting fire damage. All pillars are to comply with Part 17.

10.13 Novel features

10.13.1 Where pillars are of unusual design or constructed from novel material they will be specially considered in accordance with 2.7.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to multi-hull craft of composite construction as defined in Pt 1, Ch 1,1.

1.2 General

1.2.1 Except as otherwise specified within this Chapter, the scantlings and arrangements of multi-hull craft are to be determined in accordance with the procedures described in, or as required by Chapter 3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

1.3 Direct calculations

1.3.1 Where the craft is of unusual design, form or proportions, or where the speed of the craft exceeds 60 knots the scantlings are to be determined by direct calculation.

1.3.2 The requirements of this Chapter may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

1.4 Equivalents

1.4.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with Pt 3, Ch 1,2.

1.5 Symbols and definitions

1.5.1 Unless otherwise specified the symbols and definitions for use within this Chapter are as defined in Ch 3,1.5.

1.5.2 **Bottom outboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom outboard shell is defined as the area of the hull between the outboard edge of the keel and the outer bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures, the bottom outboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.3 **Bottom inboard**. For high speed craft, where the scantlings of the bottom shell are governed by impact pressure considerations, the bottom inboard shell is defined as the area of the hull between the inboard edge of the keel and the inner bilge tangential point. For displacement and semi displacement type craft where the scantlings of the bottom shell are governed by either hydrostatic or pitching pressures the bottom inboard shell is to extend to the chine line or 150 mm above the static load waterline, whichever is the greater.

1.5.4 **Cross-deck**. The cross-deck is defined as the structure which forms the bridge connection between any two adjacent hulls.

1.5.5 **Haunch**. The haunch is defined as the transition area between the cross-deck and the side inboard shell laminate.

1.5.6 **Side inboard**. The side inboard is defined as the area between the bottom inboard shell and the wet-deck (or lower edge of the haunches, where fitted).

1.5.7 **Side outboard**. The side outboard is defined as the area between bottom outboard shell and the deck at side.

1.5.8 **Wet-deck**. The wet-deck is defined as the area between the upper edges of the side inboard laminate (or upper edges of the haunches, where fitted).

■ *Section 2* Minimum thickness requirements

2.1 General

2.1.1 The minimum thickness requirements for single skin laminates are to be in accordance with Ch 3,2.

2.1.2 The minimum amount of reinforcement in single skin laminates which form the skins of sandwich laminate is to be in accordance with Ch 3,2. In addition, the minimum amount of reinforcement requirements of Table 4.2.1 are to be complied with. The amount of reinforcement is to be corrected for craft type, craft length and fibre content in accordance with Ch 3,2.5.

Table 4.2.1 Minimum amount of reinforcement in sandwich laminate skins

Panel location	Minimum amount of reinforcement, W_{min} (g/m^2)		Sandwich skin length factor, f_{LS}
	Glass	Carbon/ Aramid	
Bottom outboard, outer skin	3650	2700	0,33
Bottom outboard, inner skin	2850	2100	0,33
Side outboard, outer skin	3250	2400	0,33
Side outboard, inner skin	2450	1950	0,33
Wet-deck, outer skin	3250	2400	0,33
Wet-deck, inner skin	2450	1950	0,33
Cross-deck, outer skin	2450	1950	0,33
Cross-deck, inner skin	1650	1300	0,0

NOTE
The minimum amount of reinforcement in hybrid laminates will be individually considered on an equivalence basis. *See* Ch 3,2.9.2.

2.1.3 In addition, where laminates contribute to the global strength of the craft, the thickness is to be not less than that required to satisfy global strength requirements.

■ *Section 3*
Shell envelope laminate

3.1 General

3.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for the shell envelope laminate are to be determined in accordance with the procedures described in, or as required by Ch 3,3 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

3.2 Keel plates

3.2.1 The breadth, b_K, and thickness, t_K, of plate keels are not to be taken as less than:

$$b_K = 5{,}0L_R + 250 \text{ mm}$$
$$t_K = \sqrt{k_t}\ (5{,}0L_R^{\,0{,}45}) \text{ mm}$$

where

L_R = Rule length, in metres, as defined in Pt 3, Ch 2,6.1

k_t is as defined in Ch 3,2.1.

3.2.2 In no case is the thickness of the keel to be less than that of the adjacent bottom shell laminate.

3.2.3 The width and thickness of plate keels are to be maintained throughout the length of the craft from the transom to a point not less than 25 per cent of the freeboard measured at the forward perpendicular (FP) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by Ch 3,3.3.1 for the stem. Laminate tapers are to comply with Ch 3,3.14.2.

3.2.4 Where the bottom shell is of sandwich construction the keel is to be formed by locally returning to single skin construction for a width as required by 3.2.1. The Rule thickness of keel is to comprise both the inner and outer skins of the adjacent bottom shell sandwich plus additional reinforcement as required. The distribution of reinforcement in way of the plate keel and sandwich bottom structure is to be in accordance with Fig. 4.3.1. *See also* Ch 3,3.2.4.

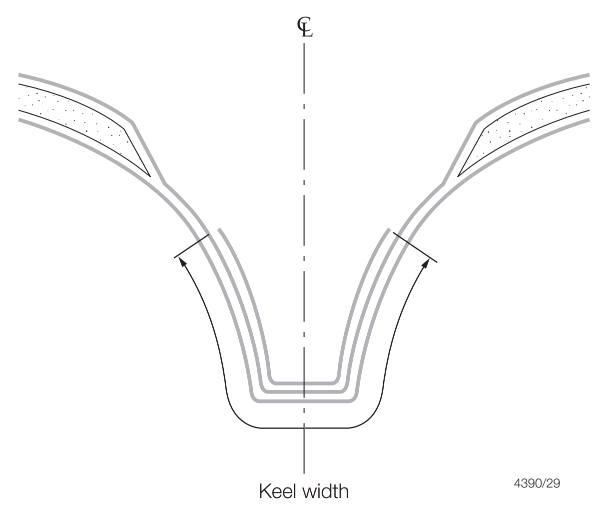


Fig. 4.3.1
Single skin/Sandwich skin intersection detail

3.2.5 For large, novel, asymmetric hull form craft, or yachts with externally attached ballast keels, or where it is proposed to incorporate keels of the 'bar' type the scantlings of the keel will be specially considered.

3.3 Bottom outboard

3.3.1 For all craft types, the minimum bottom outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 1.5.2 for displacement and semi-displacement craft.

3.3.2 The bending moment assumed to be carried by the bottom outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.3.3 and 3.3.5 respectively.

3.3.3 An estimate of the thickness of **bottom outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5,5 mm.

3.3.5 An estimate of the stiffness EI, the thickness of single skin laminate for outer and inner skins of the **bottom outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.3.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

3.3.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.3.4 and 3.3.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.4 Bottom inboard

3.4.1 The scantlings and arrangements for bottom inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the bottom inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

3.5 Side outboard

3.5.1 The side outboard shell is as defined in 1.5.7.

3.5.2 For all craft types, the minimum side outboard shell laminate thickness as required by the Rules is to be extended over the region as defined in 3.5.1 for displacement and semi-displacement craft.

3.5.3 The bending moment assumed to be carried by the side outboard shell laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.5.4 and 3.5.6 respectively.

3.5.4 An estimate of the thickness of **side outboard single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.5 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.5.6 An estimate of the stiffness EI, the thickness of single skin laminate for outer and inner skins of the **side outboard sandwich panel** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.5.7 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

3.5.8 Special consideration may be given to laminate thicknesses lesser than those required by 3.5.5 and 3.5.7, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.6 Side inboard

3.6.1 The scantlings and arrangements for side inboard shell laminate are to be determined in accordance with the procedures described in 3.3 using the side inboard shell design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate.

3.7 Wet-deck

3.7.1 The wet-deck is as defined in 1.5.8.

3.7.2 The bending moment assumed to be carried by the wet-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 3.7.3 and 3.7.5 respectively.

3.7.3 An estimate of the thickness of wet-deck single skin laminate is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR's *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.4 In no case is the minimum thickness of single skin laminate to be taken as less than 5 mm.

3.7.5 An estimate of the *EI*, the thickness of single skin laminate for outer and inner skins of the wet-deck sandwich panel and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

3.7.6 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

3.7.7 Special consideration may be given to laminate thicknesses lesser than those required by 3.7.4 and 3.7.6, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided, *see* Ch 3,2.3.1, and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

3.7.8 The wet-deck laminate on the underside of the cross-deck structure may require to be additionally protected, particularly where the air gap is small and there is a high risk of localised impact due to collision with floating debris, ice, etc., in the service area. In such cases the requirements for sheathing, given in Ch 3,2.9, are to be complied with.

3.8 Transom

3.8.1 The scantlings and arrangements of transoms are to be not less than as required for the adjacent bottom inboard or side outboard structure as appropriate.

3.8.2 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

3.9 Haunch reinforcement (SWATH)

3.9.1 For craft above 30 m in length, L_R, the stresses in the haunch area are to be derived using a two dimensional fine mesh finite element analysis. The model is to extend horizontally into the box structure and vertically into the strut structure. All discontinuities and cut-outs are to be modelled in order to determine shear stresses at critical locations and stresses for the determination of fatigue strength.

3.9.2 Due consideration is to be given to shear lag when calculating the effective breadth of the attached laminate.

3.10 Lower hull (SWATH)

3.10.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the thickness of the lower hull shell laminate may be derived from an established method for shell analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of direct calculations are to be submitted for consideration.

3.10.2 In general the design load to be used is the pressure load given in Pt 5, Ch 4,3.1. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

3.11 Novel features

3.11.1 Where the Rules do not specifically define the requirements for laminate elements with novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* **Shell envelope framing**

4.1 General

4.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for shell envelope framing are to be determined in accordance with the procedures described in, or as required by Ch 3,4 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

4.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes.

4.2 Bottom outboard longitudinal stiffeners

4.2.1 The bottom outboard longitudinal stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.2.2 Bottom outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.2.3 Where it is impracticable to comply with the requirements of 4.2.2, or where it is desired to terminate the bottom outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.2.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.2.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7 and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.3 Bottom outboard longitudinal primary stiffeners

4.3.1 The bottom outboard longitudinal primary stiffeners are to be supported by bottom transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.3.2 Bottom outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.3.3 Where it is impracticable to comply with the requirements of 4.3.2, or where it is desired to terminate the bottom outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.3.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.3.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.4 Bottom outboard transverse stiffeners

4.4.1 Bottom outboard transverse stiffeners are defined as local stiffening members which support the bottom shell, and which may be continuous or intercostal.

4.4.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.4.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.5 Bottom outboard transverse frames

4.5.1 Bottom outboard transverse frames are defined as stiffening members which support the bottom shell, they are to be effectively continuous and be bracketed at their end connections to side frames and bottom floors as appropriate.

4.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.6 Bottom outboard transverse web frames

4.6.1 Bottom outboard transverse web frames are defined as primary stiffening members which support bottom shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and bottom floors.

4.6.2 Where it is impracticable to comply with the requirements of 4.6.1, or where it is desired to terminate the bottom inboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed' (*see* Fig. 3.4.1 in Chapter 3) and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.6.3 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.6.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.7 Bottom inboard longitudinal stiffeners

4.7.1 The scantlings and arrangements for bottom inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.2 using the bottom inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.8 Bottom inboard longitudinal primary stiffeners

4.8.1 The scantlings and arrangements for bottom inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.3 using the bottom inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.9 Bottom inboard transverse stiffeners

4.9.1 The scantlings and arrangements for bottom inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.4 using the bottom inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.10 Bottom inboard transverse frames

4.10.1 The scantlings and arrangements for bottom inboard transverse frames are to be determined in accordance with the procedures described in 4.5 using the bottom inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.11 Bottom inboard transverse web frames

4.11.1 The scantlings and arrangements for bottom inboard transverse web frames are to be determined in accordance with the procedures described in 4.6 using the bottom inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.12 Side outboard longitudinal stiffeners

4.12.1 The side outboard longitudinal stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.12.2 Side outboard longitudinal stiffeners are to be continuous through the supporting structures.

4.12.3 Where it is impracticable to comply with the requirements of 4.12.2, or where it is desired to terminate the side outboard longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.12.4 The Rule requirements for the bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.12.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.13 Side outboard longitudinal primary stiffeners

4.13.1 The side outboard longitudinal primary stiffeners are to be supported by side transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.13.2 Side outboard longitudinal primary stiffeners are to be continuous through the supporting structures.

4.13.3 Where it is impracticable to comply with the requirements of 4.13.2, or where it is desired to terminate the side outboard longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.13.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.13.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.14 Side outboard transverse stiffeners

4.14.1 Side outboard transverse stiffeners are defined as local stiffening members which support the side shell, and which may be continuous or intercostal.

4.14.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.14.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.15 Side outboard transverse frames

4.15.1 Side outboard transverse frames are defined as stiffening members supporting the side shell and spanning continuously between bottom floors/frames and decks. They are to be effectively constrained against rotation at their end connections.

4.15.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.15.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.16 Side outboard transverse web frames

4.16.1 Side outboard transverse web frames are defined as primary stiffening members which support side shell longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.16.2 Where it is impracticable to comply with the requirements of 4.16.1, or where it is desired to terminate the side outboard transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.16.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.16.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.17 Side inboard longitudinal stiffeners

4.17.1 The scantlings and arrangements for side inboard longitudinal stiffeners are to be determined in accordance with the procedures described in 4.12 using the side inboard longitudinal stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.18 Side inboard longitudinal primary stiffeners

4.18.1 The scantlings and arrangements for side inboard longitudinal primary stiffeners are to be determined in accordance with the procedures described in 4.8 using the side inboard longitudinal primary stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.19 Side inboard transverse stiffeners

4.19.1 The scantlings and arrangements for side inboard transverse stiffeners are to be determined in accordance with the procedures described in 4.14 using the side inboard transverse stiffeners design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.20 Side inboard transverse frames

4.20.1 The scantlings and arrangements for side inboard transverse frames are to be determined in accordance with the procedures described in 4.15 using the side inboard transverse frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.21 Side inboard transverse web frames

4.21.1 The scantlings and arrangements for side inboard transverse web frames are to be determined in accordance with the procedures described in 4.16 using the side inboard transverse web frames design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate.

4.22 Wet-deck longitudinal stiffeners

4.22.1 The wet-deck longitudinal stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 2 m apart.

4.22.2 Wet-deck longitudinal stiffeners are to be continuous through the supporting structures.

4.22.3 Where it is impracticable to comply with the requirements of 4.22.2, or where it is desired to terminate the wet-deck longitudinal stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.22.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.22.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.22.6 In no case are the scantlings and arrangements for the wet-deck longitudinal stiffeners to be taken less than as required for the side inboard longitudinal stiffeners indicated in 4.17.

4.23 Wet-deck longitudinal primary stiffeners

4.23.1 The wet-deck longitudinal primary stiffeners are to be supported by transverse web frames, bulkheads, or other primary structure, generally spaced not more than 6 m apart.

4.23.2 Wet-deck longitudinal primary stiffeners are to be continuous through the supporting structures.

4.23.3 Where it is impracticable to comply with the requirements of 4.23.2, or where it is desired to terminate the wet-deck longitudinal primary stiffeners in way of the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets.

4.23.4 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.23.5 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.23.6 In no case are the scantlings and arrangements for the wet-deck longitudinal primary stiffeners to be taken less than as required for the side inboard longitudinal primary stiffeners indicated in 4.18.

4.23.7 Additionally the requirements of Chapter 6, in respect of global strength are to be complied with.

4.24 Wet-deck transverse stiffeners

4.24.1 Wet-deck transverse stiffeners are defined as local stiffening members which support the wet-deck shell, and which may be continuous or intercostal.

4.24.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b).

4.24.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.24.4 In no case are the scantlings and arrangements for the wet-deck transverse stiffeners to be taken less than as required for the side inboard transverse stiffeners indicated in 4.19.

4.25 Wet-deck transverse frames

4.25.1 Wet-deck transverse frames are defined as stiffening members which support the wet-deck shell, they are to be effectively continuous and be bracketed at their end connections to side frames and side floors as appropriate.

4.25.2 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.25.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.25.4 In no case are the scantlings and arrangements for the wet-deck transverse frames to be taken less than as required for the side inboard transverse frames indicated in 4.20.

4.26 Wet-deck transverse web frames

4.26.1 Wet-deck transverse web frames are defined as primary stiffening members which support wet-deck longitudinals, they are to be continuous and be substantially bracketed at their end connections to side web frames and side floors.

4.26.2 Where it is impracticable to comply with the requirements of 4.26.1, or where it is desired to terminate the wet-deck transverse web frames in way of bulkheads or integral tank boundaries, etc., all web frames are to be bracketed in way of their end connections, to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. All brackets are to be 'soft toed', *see* Fig. 3.4.1 in Chapter 3, and are to terminate on suitable supporting structure capable of carrying the transmitted bending moment.

4.26.3 The Rule requirements for bending moment, shear force, shear stress and deflection are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

4.26.4 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

4.26.5 In no case are the scantlings and arrangements for the wet-deck transverse web frames to be taken less than as required for the side inboard transverse web frames indicated in 4.21.

4.26.6 Primary transverse web frame members which link the strength deck to the wet-deck structure and which carry the transverse global loading, are additionally to comply with Ch 6,3.4.

4.26.7 Particular care is to be taken to ensure that the continuity of transverse structural strength is maintained. All primary transverse members are to be continuous through the side inboard structure and be integrated into transverse bulkheads or other primary structure within each hull, *see* Fig. 4.4.1. In the case of trimaran type craft the primary transverse members are to be continuous through the centre hull. Additionally the side inboard shell laminate in way of the intersection is to be locally increased in thickness by not less than 50 per cent. Copies of direct calculations are to be submitted for consideration.

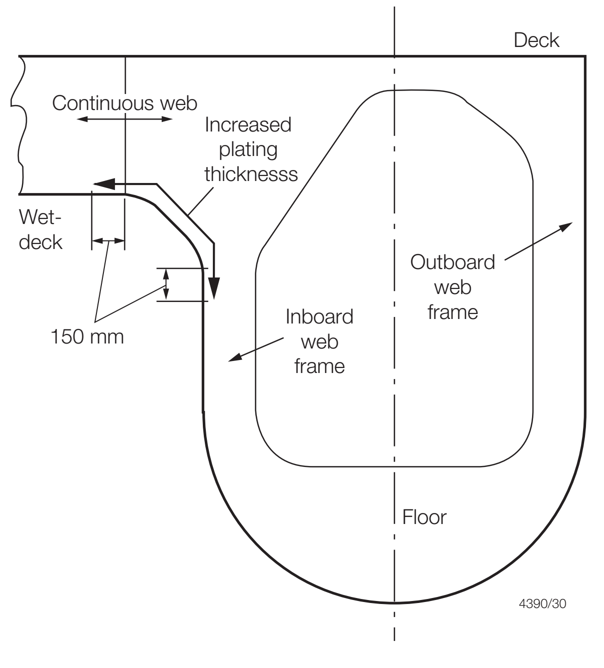


Fig. 4.4.1
End connection detail, wet-deck structure

4.27 Novel features

4.27.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 5* Single bottom structure and appendages

5.1 General

5.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for single bottom structure and appendages are to be determined in accordance with the procedures described in, or as required by Ch 3,5 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

5.1.2 The minimum thickness requirements detailed in 2.1 are to be complied with as appropriate.

5.2 Keel

5.2.1 The scantlings and arrangements of plate keels are to be in accordance with 3.2. Where it is proposed to incorporate keels of the bar type such arrangements would require to be specially considered.

5.3 Centre girder

5.3.1 Centreline girders are to be fitted throughout the length of each hull and are generally to be fitted in association with transverse frames, transverses supporting longitudinals or where the breadth of floors at the upper edge is greater than 1,5 m.

5.3.2 Centreline girders may be formed with intercostal or continuous top hat or plate webs. Where girder webs are intercostal, additional bracketing and local reinforcement as given in Ch 3,3.14 are to be provided to maintain the continuity of structural strength. The face reinforcement in all cases is to be continuous.

5.3.3 The web depth of the centre girder in general is to be equal to the depth of the floors at the centreline as specified in 5.5.

5.3.4 The web thickness, t_w, for a centre girder of 'top-hat' type section is to be not less than that required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\sqrt{L_R} + 1{,}37\right) \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

5.3.5 The web thickness for a centre girder of single plate laminate construction is to be two times the thickness as required by 5.3.4.

5.3.6 The face area of the centre girder, A_f, is to be not less than:

$$A_f = 1{,}18 L_R\, k_A \quad \text{cm}^2$$

where

$$k_A = \frac{85}{\sigma_u}$$

σ_u = ultimate tensile strength of the face area laminate, in N/mm^2
L_R = as defined in Ch 3,1.5.1.

5.3.7 The face area of the centre girder outside $0{,}5L_R$ about midships may be reduced to 80 per cent of the value given in 5.3.6.

5.3.8 The face thickness, t_f, is to be not less than the web thickness of the centre girder.

5.3.9 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4 Side girder

5.4.1 Where the floor breadth at the upper edge exceeds 4,0 m side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

5.4.2 In the engine room, additional side girders are generally to be fitted in way of the main machinery.

5.4.3 The face area of side girders, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R\, k_A \quad \text{cm}^2$$

where
k_A and L_R are as defined in Ch 3,1.5.1.

5.4.4 The web thickness, t_w, for side girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{0{,}66 k_A\, L_R} \quad \text{mm}$$

where
k_A and L_R are as defined in Ch 3,1.5.1.

5.4.5 The web thickness for side girders of single plate laminate construction is to be two times the thickness as required by 5.4.4.

5.4.6 Additionally, the requirements of 4.8 for bottom longitudinal primary stiffeners are to be complied with.

5.4.7 Watertight side girders, or side girders forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3. and Ch 3,7.4 respectively.

5.5 Floors

5.5.1 In transversely framed craft, floors are generally to be fitted at every frame and underneath each bulkhead.

5.5.2 In longitudinally framed craft, floors are to be fitted at every transverse web frame and bulkhead and generally at a spacing not exceeding 2 m. Additional transverse floors or webs are to be fitted at half web-frame spacing in way of engine seatings and thrust bearings, pillars, skegs, ballast/bilge keels and the bottom of the craft in the forefoot region.

5.5.3 The overall depth of transverse floors at the centreline, d_W, is not to be taken as less than:

$$d_W = 6{,}2 L_R + 50 \quad \text{mm}$$

5.5.4 The web thickness, t_w, for transverse floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\left(\frac{4{,}33 d_W}{1000} + 2{,}75\right)\left(\frac{s}{1000} + 0{,}5\right) \quad \text{mm}$$

where
d_W = as defined in 5.5.3
k_A and s are as defined in 5.3.6.

5.5.5 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 5.5.4.

5.5.6 If the side frames of the craft are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

5.5.7 The face area of floors, A_f, is not to be taken as less than:

$$A_f = 0{,}82 L_R\, k_A \quad \text{cm}^2$$

where
k_A and L_R are as defined in Ch 3,1.5.1.

5.5.8 The thickness of the face laminate, t_f, is to be not less than the web thickness.

5.5.9 In addition, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

5.5.10 Floors are generally to be continuous from side to side.

5.5.11 The tops of floors, in general, may be level from side to side. However, in craft having considerable rise of floor the depth of the floor plate may require to be increased to maintain the required mechanical properties of the section.

5.5.12 The floors in the aft peak are to extend over and provide efficient support to the stern tube(s) where applicable.

5.5.13 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with the requirements for watertight bulkheads or deeptanks as detailed in Ch 3,7.3 or Ch 3,7.4 respectively.

5.6 Floors in machinery space

5.6.1 The depth and mechanical properties of floors between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in 5.5.3. The web thickness and face reinforcement weight of such reduced height floors are to be increased appropriately in order to maintain the continuity of structural strength.

5.7 Lower hull (SWATH)

5.7.1 Where the lower hull structure incorporates ring frames and attached shell laminate fitted between bulkheads or diaphragms, the scantlings of the lower hull shell stiffening may be derived from an established method for stiffening analysis or recognised standard for pressure vessels. Modes of failure to be considered are buckling, frame collapse, inter frame shell collapse and overall frame shell collapse between bulkheads. Copies of detailed calculations are to be submitted for consideration.

5.7.2 In general, the design load used is to be the design pressure from Pt 5,Ch 3,3.1 or Pt 5, Ch 4,3.1 for non-displacement or displacement craft as appropriate. If other loads are considered to be of significance for the scantling determination these are to be taken into account.

5.8 Forefoot and stem

5.8.1 The scantlings and arrangements for the forefoot and stem construction are to be in accordance with Ch 3,5.11.

5.9 Transom knee

5.9.1 Transom knees are to be fitted in each hull as necessary in accordance with Ch 3,5.12.

■ *Section 6*
Double bottom structure

6.1 General

6.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for double bottom structure are to be determined in accordance with the procedures described in, or as required by Ch 3,6 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

6.1.2 The minimum thickness requirements detailed in Ch 3,2.1 are to be complied with as appropriate.

6.2 Keel

6.2.1 The breadth and thickness of plate keels are to comply with the requirements of 3.2.

6.3 Centreline girder

6.3.1 A centreline girder is to be fitted throughout the length of each hull. The web thickness, t_w, of centre girders of 'top-hat' type section is to be not less than as required by Ch 3,1.16. or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}073L_R + 3{,}64) \text{ mm within } 0{,}4L_R \text{ amidships}$$

$$= \sqrt{k_A}\ (0{,}073L_R + 2{,}73) \text{ mm at ends}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.3.2 The web thickness for a centreline girder of single plate laminate construction is to be two times the thickness as required by 6.3.1.

6.3.3 The overall depth of the centreline girder, d_{DB}, is not to be taken as less than 630 mm and is to be sufficient to give adequate access to all parts of the double bottom.

6.3.4 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.4 Side girders

6.4.1 Where the breadth of the floor at the upper edge, within a single hull, does not exceed 4,0 m, side girders are not required. Vertical stiffeners are to be fitted to the floors on each side of the centreline girder, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

6.4.2 Where the breadth of the floor at the upper edge, within a single hull, exceeds 4,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. Side girders, where fitted, are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

6.4.3 Under the main engine, girders extending from the bottom to the top plate of the engine seating are to be fitted. The height of the girders is not to be less than the height of the floor. Engine holding-down bolts are to be arranged as near as practicable to the girders and floors. Where this cannot be achieved, bracket floors are to be fitted.

6.4.4 Side girders are to have a minimum web thickness, t_w, as required by Ch 3,1.16 but not less than as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}064L_R + 4{,}32) \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.4.5 Additionally, the requirements of 4.8 for bottom inboard longitudinal primary stiffeners are to be complied with.

6.5 Plate floors

6.5.1 Plate floors may be of single skin, sandwich skin or 'top-hat' type construction, and are to comply with the requirements of 5.5 where applicable.

6.5.2 The web thickness, t_w, of non-watertight plate floors of 'top-hat' type section is to be not less than as required by Ch 3,1.16 or as determined as follows whichever is the greater and in no case is t_w to be taken less than 5,0 mm:

$$t_w = \sqrt{k_A}\ (0{,}036L_R + 4) \text{ mm}$$

where

k_A and L_R are as defined in Ch 3,1.5.1.

6.5.3 The web thickness for transverse floors of single plate laminate construction is to be two times the thickness as required by 6.5.2.

6.5.4 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

6.5.5 Additionally, the requirements of 4.11 for bottom inboard transverse web frames are to be complied with.

6.5.6 Plate floors are generally to be continuous between the centre girder and the margin plate.

■ *Section 7*
Bulkheads and deep tanks

7.1 General

7.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for bulkheads and deep tanks are to be determined in accordance with the procedures described in, or as required by Ch 3,7 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

7.1.2 The scantlings of non-watertight or partial bulkheads are in general to be as required for watertight bulkheads. Non-watertight or partial bulkheads supporting hull framing are to have scantlings equivalent to frames or web frames as appropriate, in the same position.

7.1.3 Sandwich wood bulkheads, plywood bulkheads or other forms of bulkhead construction will be considered on the basis of equivalent strength.

7.2 Longitudinal bulkheads within cross-deck structure

7.2.1 Longitudinal bulkheads are to be fitted within the cross-deck structure to prevent cross flooding and the spread of flame and smoke. The minimum number of such bulkheads is to be two for catamarans and four for trimarans. Quadrimarans and other craft of novel configuration will be specially considered.

7.2.2 The scantlings and arrangements of cross-deck longitudinal bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.2.3 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.3 Transverse bulkheads within the cross-deck structure

7.3.1 The scantlings and arrangements of cross-deck transverse bulkheads are to be determined in accordance with the procedures described in Ch 3,7.3 and Ch 3,7.4 for bulkheads in mono-hull craft.

7.3.2 In addition the requirements of 7.4 in respect of global strength are to be complied with.

7.4 Additional strength required for global loadings

7.4.1 Where transverse bulkheads or deep tank bulkheads within the cross-deck structure are to assist in resisting torsional or bending loads between the hulls, then the watertight/deep tank bulkheads may be required to be additionally stiffened and the laminate or skin thicknesses may require to be increased. For hull girder strength requirements, *see* Ch 6,3.

7.4.2 Longitudinal bulkheads within the cross-deck structure that are to assist in maintaining the longitudinal strength of the vessel are to satisfy both bulkhead/deep tank and longitudinal strength requirements. This may require additional stiffening and increase in plate thickness requirements. For hull girder strength requirements, *see* Ch 6,3.

7.4.3 Where longitudinal or transverse cross-deck bulkheads/deep tanks are to carry global loads, detailed calculations are to be submitted.

7.4.4 For longitudinal or transverse cross-deck members carrying global loads, consideration is to be given to stiffener arrangement, alignment, and continuity in order to maximise the rigidity and stiffness of the structure, in resisting the torsional/bending loads. Due consideration is to be given to the wrinkling and buckling of the skins of sandwich plate laminates. Discontinuity of structural bulkheads is to be avoided.

7.5 Access

7.5.1 Access through the cross-deck structure may be permitted, provided that the global strength requirements are satisfied. Cut-outs through the bulkhead are not to exceed 50 per cent of its depth. The edges of cut-out in sandwich panels are to be suitably reinforced while those of single skin construction are to be sealed.

7.5.2 Where the cross-deck structure acts as a water-tight bulkhead pipe or cable runs through, the watertight bulkheads are to be fitted with suitable watertight glands.

7.6 Local strength

7.6.1 Bulkheads that form the cross-deck structure are to be suitably strengthened, if necessary, at the ends of deck girders and where subjected to concentrated loads.

7.7 Integral/deep tanks within cross-deck structure

7.7.1 Where the cross-deck structure forms the boundaries of deep tanks, the scantlings of these boundaries are to satisfy both deep tank and global strength requirements. For general and structural requirements for deep tanks, *see* Ch 3,7.4. For global considerations of strength, *see* Ch 6,3.

■ *Section 8* Deck structures

8.1 General

8.1.1 Except as otherwise specified within this Section, the scantlings and arrangements for deck structures are to be determined in accordance with the procedures described in, or as required by Ch 3,8 for mono-hull craft, using the pressures from Part 5 appropriate to multi-hull craft.

8.1.2 Deck structures are to comply with the minimum thickness requirements of Section 2.

8.1.3 Special attention is to be given to the connections of primary transverse beams to hull side web frames in order to provide adequate load distribution and avoid stress concentrations.

8.1.4 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

8.1.5 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

8.1.6 Design loads to be applied for cross-deck scantling calculations are transverse vertical bending moment and shear force, twin hull torsional connecting moment, external pressure load and appropriate internal loads as defined in Part 5.

8.2 Arrangements

8.2.1 Deck structures are to comply with the longitudinal and transverse global strength requirements given in Chapter 6.

8.3 Symbols and definitions

8.3.1 The term ‘cross-deck’ is used in this Section for the bridging deck, connecting two or more hulls, carrying global transverse loads. *See also* 1.5.4.

8.4 Cross-deck laminate

8.4.1 The bending moment assumed to be carried by the cross-deck laminate is to be not less than that determined by Ch 3,1.9.1, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate. This bending moment is to be applied to laminates of both single skin and sandwich construction in the determination of the panel scantling required by 8.4.2 and 8.4.4 respectively.

8.4.2 An estimate of the thickness of **strength/weather deck single skin laminate** is to be determined from Ch 3,1.12.1. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.12.3 and Ch 3,1.12.4, *see also* LR’s *Guidance Notes for Calculation Procedures for Composite Construction*. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.3 In no case is the minimum thickness of single skin laminate to be taken as less than 4 mm.

8.4.4 An estimate of the stiffness, *EI*, thickness of single skin laminate for outer and inner skins of the **strength/weather deck sandwich panels** and the thickness of core material is to be determined from Ch 3,1.13.2 and Ch 3,1.13.9 respectively. The tensile and compressive stresses are to be determined for each ply of reinforcement in the proposed laminate using Ch 3,1.13.7 and Ch 3,1.13.8. The allowable tensile and compressive stress limits indicated in Table 7.3.1 in Chapter 7 are to be complied with.

8.4.5 The amount of reinforcement in laminates that form the skins of a sandwich laminate is to comply with the requirements of 2.1.2.

8.4.6 Special consideration may be given to laminate thicknesses lesser than those required by 8.4.3 and 8.4.5, provided that all of the structural strength requirements of the Rules are complied with, a satisfactory water barrier is provided and the equivalent impact resistance is demonstrated as required by Ch 3,2.8.2.

8.4.7 The scantlings of watertight cockpits are to be of equivalent strength to those for the strength/weather deck, *see also* Part 4.

8.4.8 It is recommended that working areas of the weather deck have an anti-slip surface.

8.4.9 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also* Ch 3,2.9.

8.5 Cross-deck stiffening

8.5.1 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck primary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4.3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (a).

8.5.2 The Rule requirements for bending moment, shear force, shear stress and deflection for the cross-deck secondary stiffeners are to be determined from the general equations given in Ch 3,1.14, using the design pressure from Pt 5, Ch 3,3.1, or Pt 5, Ch 4,3.1 for non-displacement or displacement type craft as appropriate, and the coefficients ϕ_M, ϕ_S and ϕ_δ as indicated in Table 3.1.10 in Chapter 3 for the load model (b). Special consideration will be given to the application of other load models subject to the structural arrangement and degree of end fixity provided.

8.5.3 The allowable tensile, compressive and shear stress limits indicated in Table 7.3.1 in Chapter 7, and the span/deflection ratios indicated in Table 7.2.1 in Chapter 7 are to be complied with.

8.5.4 The geometric properties of stiffener sections are to be calculated in accordance with Ch 3,1.15 using an effective width of attached laminate as given in Ch 3,1.7.

8.5.5 For cases where there may be excessive rotations or deflections at supports or where the lateral pressure distribution is non-uniform, the above scantlings may have to be increased appropriately.

8.5.6 Where stiffeners are subject to concentrated loads such as pillars, the concentrated loads are to be superimposed on the lateral pressure and strength calculations carried out to demonstrate compliance with the deflection and stress criteria given in Table 7.2.1 in Chapter 7 and Table 7.3.1 in Chapter 7.

8.5.7 Where the floating frame system is used, the effect of the plating attached to the stiffening members is to be ignored when calculating the required section stiffness, EI, of the primary stiffening members, i.e. the full stiffness, EI, is to be provided by the primary stiffening members only.

8.5.8 Openings in the cross-deck for hatches etc., are to comply with the requirements of Ch 3,8.12.

8.6 Novel features

8.6.1 Where the cross-deck structure is of unusual design, form or proportions, the scantlings are to be determined by direct calculation, *see* Ch 3,2.7.

■ *Section 9*
Superstructures, deckhouses, bulwarks and pillars

9.1 General

9.1.1 The scantlings and arrangements for superstructures, deckhouses and bulwarks are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,9.

9.1.2 The scantlings and arrangements for pillars are to be determined in accordance with the procedures described in, or as required for mono-hull craft indicated in Ch 3,10.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to both mono-hull and multi-hull craft of composite construction.

1.2 Symbols and definitions

1.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

■ *Section 2* Special features

2.1 Water jet propulsion systems – Construction

2.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

2.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate:

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

2.1.3 When submitting the plans requested in 2.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted and are to include maximum applied thrust, moments and tunnel pressures for which approval of the propulsion system is sought.

2.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.1.5 Aluminium alloys, where used, are to be of suitable marine grades in accordance with the requirements of Part 7.

2.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

2.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

2.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

2.1.9 The leading edges of FRP tunnels are to be additionally reinforced by suitable means. Proposals are to be submitted as required by 2.1.2.

2.1.10 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

2.1.11 For details of machinery requirements, *see* Pt 10, Ch 2, Machinery Requirements.

2.2 Water jet propulsion systems – Installation

2.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also* 2.1.4.

2.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by 2.1.2.

2.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the laminate adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom laminate thicknesses respectively or 12 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

2.2.4 For 'bolted in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to bonding in place. The receiving ring is to be installed using an approved laminating procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

2.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

2.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than 0,2 times the thickness of the receiving ring or 5 mm whichever is the greater. Bottoms of all blind taps are to be free of sharp corners.

2.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

2.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved laminating procedure and in accordance with the manufacturer's instructions. Materials to be laminated are to be of compatible specifications.

2.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

2.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details and calculations for which are to be submitted.

2.2.11 In general, sandwich skin laminates in way of water jet installations are to be brought together to form single skins complying with 2.2.3. Proposals to use sandwich construction in way of installations will be specially considered, subject to the use of appropriate structural core materials and direct calculations being submitted in support.

2.2.12 Exposed edges of laminates subject to water flow are to be over laminated and protected by suitable means; proposals are to be submitted for consideration.

2.2.13 Where the jet-unit is an FRP premoulding of an approved type, the surface of the unit is to be suitably abraded and degreased prior to installation in the mould tool and subsequent over laminating of the main hull structure. Particular care is to be given to material compatibility of the resin system used for the premould and main hull laminate.

2.3 Foil support arrangements

2.3.1 The materials and construction of the lifting surface will be considered on a case by case basis.

2.3.2 The design and performance of the lifting surface is outside the scope of classification. However, when submitting structural plans for the hull connection installation, the designer/Builder is to define:

(a) Operating mode, i.e. fully submerged or surface piercing.
(b) Maximum operational speed for which approval is sought.
(c) Maximum, direct, bending, shear and torque loads generated by the foil at the point of attachment(s).
(d) The type of profile or section used, e.g. N.A.C.A.
(e) Supply of lift/drag profile.
(f) If the foil is fixed, movable or retractable.
(g) If the foil is fitted with control surfaces.
(h) If the vertical leg(s) act as a rudder(s).
(j) If shaft liners are carried to the foils at which support arrangements are provided.
(k) If water intakes/scoops are fitted.
(l) If propulsion units are fitted.

2.3.3 The scantlings and arrangements of foils and their supporting structure will be required to be specially considered in the following cases where:

(a) Propulsion units are incorporated within the foil.
(b) Foils carry shaft support arrangements.
(c) The foils are of novel design.

2.3.4 Where fully submerged foils are 'built-in' to the hull, the attachment area is to be contained within a watertight compartment. The structural arrangements of 2.4 are to be complied with as appropriate.

2.3.5 Where foils are to be bolted to the structural foundation and not 'built in', calculations are to be submitted. These are to demonstrate that the effect of loading arising from high speed impact, grounding, fouling, etc., is limited to failure of the bolted connection. In all cases the structural and watertight integrity of the craft is to be maintained.

2.3.6 Attachment points of foils are in all cases to be contained within a watertight compartment.

2.3.7 Foils attached by rivetted means are, in addition, to comply with Pt 7, Ch 2,4.25.

2.3.8 Bow fairing doors fitted on forward retracting bow foils are to be weathertight and are to comply with the requirements of Pt 3, Ch 4.

2.3.9 Aft bulkheads of bow foil compartments are to comply with the requirements for collision bulkheads as detailed in Ch 3,7.6.

2.3.10 Hydraulically operated retracting systems are to be equipped with low pressure alarms, together with a manual system of operation in the event of system failure.

2.3.11 A mechanical locking system is to be provided on retracting systems when the system is in both the operational and 'stowed' conditions.

2.4 Surface drive mountings

2.4.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc., are to be adequately reinforced.

2.4.2 The thickness of transom laminate is to be not less than 50 per cent greater than the adjacent plating or as advised by the drive manufacturer, whichever is the greater.

2.4.3 Steering rams are to be mounted on suitably reinforced areas of laminate supported by additional internal stiffening; details are to be submitted for consideration.

2.5 Sea inlet scoops

2.5.1 Sea inlet scoops may be integral with or an appendage to the hull.

2.5.2 Scoops are to be suitably positioned to minimise ventilation.

2.5.3 Suitable protective arrangements are to be provided to minimise the ingress of debris. The net area through the proposed arrangement is to be not less than twice that of the valves connected to the scoop. Provision is to be made for clearing the scoops by the use of suitable means; proposals are to be submitted.

2.5.4 Scoops are to be contained within a watertight compartment.

2.5.5 The laminate thickness in way of integral scoops is to be not less than 50 per cent greater than that of the adjacent shell laminate, with additional reinforcement at the leading edge.

2.5.6 For all composite construction, scoops are to be fitted as bolted appendages.

2.5.7 For craft navigating in ice, the arrangements will be specially considered on an individual basis.

2.6 Crane support arrangements

2.6.1 Crane pedestals are to be efficiently supported and, in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise of a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

2.6.2 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the craft's heel and trim. The designer's calculations for loadings are to be indicated on the plans to be submitted.

2.6.3 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

2.6.4 When submitting plans for the proposed foundation, the designer is to include his design calculations covering the parameters indicated in 2.6.2.

2.6.5 The deck laminate is to be additionally reinforced in way of crane foundations. The thickness of reinforcement is to be that required by the designer's calculations but in no case less than 50 per cent the thickness of the adjacent plating.

2.6.6 Laminate tapers are to be in accordance with Ch 2,3.9.

2.7 Skirt attachment

2.7.1 The design and scantlings of the skirt are, in general, outside the scope of classification, however the designers/builders are to submit their proposals in respect of the attachment detail. The following supporting information is to be submitted:

(a) Cushion pressure,
(b) Calculations demonstrating that the effect of damage to the flexible membrane and/or the retaining section arising from high speed impact, grounding, fouling, etc., will not compromise the structural and watertight integrity of the craft.

2.7.2 The skirt is to be securely attached around its periphery. The supporting structure is to be suitably reinforced by the use of tapping plates incorporated into the laminate.

2.7.3 Where the skirt is retained by bolting the retaining bars are to be as long as practicable, with the fasteners being spaced not more than 50 mm apart.

2.7.4 Where the design of the skirt is such that the flexible edge is retained by the use of a pre-formed channel, only the bolted connection of the preform to the hull structure is to be considered.

2.8 Trim tab arrangements

2.8.1 The shape, design and scantlings of the trim tab are outside the scope of classification, however Lloyd's Register (hereinafter referred to as 'LR') is concerned with their attachment to the hull structure.

2.8.2 The designer/Builder is to submit the following:

(a) Detailed calculations indicating the maximum lift force generated by the tab for which acceptance is sought together with the corresponding speed and displacement.
(b) Details of the hull attachment and loadings in way for the trim tab and actuation system.
(c) Details and calculations of the local internal reinforcement to resist the loading in way of the attachment.

2.8.3 Bearing materials used are to be of an approved type.

2.8.4 Fully submerged retractable trim tabs will be specially considered on a case by case basis.

2.9 Spray rails

2.9.1 Spray rails are, in general, to be integrated into the hull structure but may be added in the form of an appendage on completion of the hull shell.

2.9.2 Where spray rails are integrated, they are to have a laminate thickness not less than the adjacent bottom shell and additionally have section properties equivalent to that required for a longitudinal stiffener in the same position.

2.9.3 Where spray rails are added as an appendage, they are to be attached in accordance with an approved bonding/laminating procedure and are additionally to comply with the strength requirements of 2.9.2. Composite preforms bonded to the outer hull are to be manufactured and bonded using approved materials, compatible with the hull laminate.

2.9.4 Spray rails are to be supported by the internal stiffening arrangements and by additional local reinforcement as necessary, as given in Ch 3,3.14.

2.9.5 In no case are the toes of spray rails to terminate on unsupported shell laminate.

2.9.6 In sandwich construction the outer skin is to be a smooth continuous surface, with spray rails attached as required by 2.9.3.

2.10 Other lifting surfaces

2.10.1 Other lifting surfaces not specifically covered by the Rules will be individually considered on the basis of submitted direct calculations.

2.10.2 Structure or hull shapes above the running waterline designed to generate aerodynamic lift may be individually considered on a case by case basis.

2.10.3 Aerodynamic, hydrodynamic and aero-hydrodynamic stability are outside the scope of classification and are subject to the approval of the National Administration concerned.

2.11 Propeller ducting

2.11.1 Where propellers are fitted within ducts/tunnels the laminate weight in way of the blades is to be increased by 50 per cent.

2.11.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

2.12 Ride control ducting and installation for Surface Effect Ships (SES)

2.12.1 Ducts penetrating the side inboard shell plating are to comply with the scantling requirements for side inboard structures, over their entire length, in the appropriate material.

2.12.2 Ducts penetrating the wet-deck are to comply with the scantling requirements for wet-deck structures over their entire length, in the appropriate material.

2.12.3 Open ends of ducts are to be fitted with a suitable protective grille.

2.12.4 The vent assembly, its design, construction and operation is outside the scope of classification and is the responsibility of the ride control system designer.

2.12.5 Details of the installation and securing arrangements of the vent valve assembly into the duct are to be submitted for approval.

■ *Section 3* Vehicle decks

3.1 General

3.1.1 Where it is proposed to construct vehicle decks in FRP composite materials, each case will be subject to individual consideration. The scantlings are to be determined by direct calculation or on the basis of the requirements of Chapter 3, in conjunction with the procedures, loadings and general requirements for vehicle decks of aluminium alloy construction, as indicated in Pt 7, Ch 5.

3.1.2 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material. Such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

3.1.3 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck or hatch cover, as applicable.

3.1.4 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the craft's documentation and contained in a notice displayed on each deck. For design purposes, the wheel loading is to be taken as not less than 3,0 kN.

3.1.5 The scantling requirements are based on structural strength and limitations on stress and deflection, with no allowance made for wear and tear. Local reinforcement as given in Ch 3,3.14 is to be fitted as necessary, particularly in way of vehicle lanes and passenger routes.

3.1.6 Deck fittings in way of vehicle lanes are to be recessed.

3.2 Securing arrangements

3.2.1 Details of the loads and connections to the hull of vehicle securing arrangements are to be indicated on the plans submitted with the Designer's calculations.

3.3 Access

3.3.1 Where access to the vehicle deck is provided by bow, side and stern doors, these openings are to comply with the requirements of Pt 3, Ch 4,4.

3.3.2 Doors providing pedestrian access between vehicle decks and accommodation spaces are to be gastight, and have scantlings and fire restricting characteristics equivalent to the surrounding structure, *see also* Part 17.

3.4 Hatch covers

3.4.1 The scantlings and arrangements of hatch covers located within vehicle decks are to be not less than those required by the Rules for the supporting structure in which such hatches are fitted. In general, the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

3.4.2 In no case, however, are the scantlings of plate or sandwich laminates and stiffeners to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

3.4.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations using a two-dimensional grillage determination.

3.5 Heavy and special loads

3.5.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

3.5.2 Due account is to be taken of the acceleration levels due to craft motion applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

3.6 Direct calculations

3.6.1 LR will consider direct calculations for the derivation of vehicle deck scantlings as an alternative and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with Pt 3, Ch 1,2.

■ *Section 4* Movable decks

4.1 Classification

4.1.1 Movable decks other than those described in 4.1.2 are not a classification item, although consideration is to be given to the associated supporting structure. Where movable decks are fitted, it is recommended that they are to be based on the requirements of this Section.

4.1.2 At the Owner's or Builder's request, however, movable decks will be included as a classification item, and the class notation **Removable decks** will be entered in the *Register Book*. In such cases, all movable decks on board the craft are to comply with the requirements of this Section.

4.2 Arrangements and designs

4.2.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

4.2.2 Positive means of control are to be provided to secure decks in the lowered position.

4.2.3 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

4.2.4 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

4.2.5 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc., are to be submitted for consideration.

4.3 Loading

4.3.1 The loading requirements for movable decks are to be in accordance with 3.1.

4.3.2 Where it is proposed also to use the decks for general cargo, the design loadings are to be submitted for consideration.

4.4 Scantling determination

4.4.1 The scantlings and arrangements of movable decks are to be not less than required by the Rules for the supporting structure in which they are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

4.5 Deflection

4.5.1 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during loading or unloading operations.

4.6 Direct calculations

4.6.1 As an alternative to the requirements of 4.3 to 4.5, the structure may be designed on the basis of a direct calculation using a grillage idealisation. The method adopted and the stress levels proposed for the material of construction are to be submitted for consideration, *see also* Pt 3, Ch 1,2.

■ *Section 5*
Helicopter landing areas

5.1 General

5.1.1 Where it is proposed to construct helicopter landing areas in FRP composite materials, each case will be subject to individual consideration.

5.1.2 Helicopter landing areas are to be designed to suit the largest helicopter type which it is intended to use. In general, the diameter of the landing area is to be not less than 1,25 times the rotor diameter.

5.1.3 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the craft.

5.1.4 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of helicopters to be used are also to be indicated. Details of the helicopter types to be used are to be included in the craft's documentation, and be contained in a notice displayed on the helicopter landing deck.

5.1.5 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

5.1.6 The requirements for fire protection, detection and extinction are to comply with Part 17. Special consideration is to be given to the insulation standard if the space below the helicopter deck is a high fire-risk space.

5.1.7 It is recommended that single skin laminate construction incorporating longitudinal or transverse stiffening is to be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

5.2 Symbols

5.2.1 The symbols in this Section are as defined in Ch 3,1.5.1 and in the appropriate sub-Section.

5.3 Arrangements

5.3.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the helicopter, and is to be approached by a clear landing and take-off sector complying in extent with the applicable regulations.

5.3.2 The landing area is to be free of any projections above the level of the deck. Projections in the zone surrounding the landing area are to be kept below the heights permitted by the regulations.

5.3.3 Suitable arrangements are to be made to minimise the risk of personnel or machinery sliding off the landing area. A non-slip surface and anchoring devices are to be provided.

5.3.4 Arrangements are to be made for drainage of the platform, including drainage of spilt fuel.

5.3.5 Details of the connections to the hull of helicopter securing arrangements are to be submitted for approval.

5.3.6 Engine uptake arrangements are to be sited such that exhaust gases cannot be drawn into helicopter engine intakes during helicopter take off or landing operations.

5.4 Loadings

5.4.1 The load cases to be investigated are to be not less than those required by Pt 7, Ch 5,6 for helicopter landing areas of aluminium alloy construction.

5.4.2 The proposed loadings are to be agreed with LR prior to scantling analysis and submission of structural plans for appraisal.

5.4.3 Details of the deck loading resulting from the proposed stowage arrangements of helicopters are to be supplied by the Builder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the helicopter. For design purposes the wheel loading is to be taken as not less than 3,0 kN (0,3 tonne-f).

5.4.4 Where it is proposed also to use the decks for general cargo or other alternative use, the design loadings are to be submitted for consideration.

5.5 Scantlings

5.5.1 The scantlings and arrangements of helicopter landing areas are to be not less than those required by the Rules for the supporting structure in which the helicopter landing areas are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

■ *Section 6* Strengthening requirements for navigation in ice conditions

6.1 General

6.1.1 Where an ice class notation is to be included in the class of a craft, the scantlings will require special consideration, *see* Pt 3, Ch 2,9.

6.2 Shell laminate

6.2.1 It is assumed that single skin laminate construction incorporating longitudinal or transverse stiffening will be adopted. Where it is proposed to use sandwich skin construction, particular care is to be given to the selection of the core material; such proposals will require to be specially considered, and testing may be required to demonstrate the suitability of the panels.

6.2.2 In way of the main ice belt zone, the thickness of the shell laminate is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.2.3 Changes in laminate thicknesses are to take place gradually, and in no case is the length of taper to be less than 20 times the difference in thickness. Additionally individual plies of the laminate are to be arranged such that any delamination will be directed to the outer surface of the laminate.

6.3 Shell framing

6.3.1 The web thickness for ice framing members of top-hat or plate section is to be determined by direct calculation. A copy of these calculations is to be submitted for consideration.

6.3.2 Ice frames are to be attached to the shell plating by double primary bonding angles in accordance with Ch 3,1.18. The web area of ice frames is to be maintained; air and drain holes are to be kept to a minimum.

6.3.3 The bending moment assumed to be carried by the ice framing stiffening member is not to be taken as less than 50 per cent greater than that required by the appropriate Section of the Rules for the stiffening member subjected to hydrostatic or pitching pressure whichever is the greater.

6.4 Stem construction

6.4.1 The stem is to be additionally protected/ reinforced by a metallic shoe or other equivalent arrangement. The shoe/reinforcement is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by closely spaced floors, brackets or webs. Details of such protection and the method of attachment are to be submitted for consideration.

6.4.2 Attachment by mechanical means such as bolting or other methods is not to impair the watertight integrity of the craft. Through bolting of the hull is to be kept to a minimum and avoided where practicable.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength for both mono-hull and multi-hull craft of composite construction, are contained within this Chapter. Due consideration is taken of the dynamic effects, where appropriate, in both the crest and trough wave landing conditions.

1.2 Symbols and definitions

1.2.1 Unless specified otherwise the symbols used in this Chapter are defined as follows:

a_i = cross sectional area of the individual ply, *i*, in m^2

E_{ci} = compressive modulus of individual ply, *i*, in N/mm^2

E_i = E_{ti}, or E_{ci} of the individual ply *i*, relative to its position above or below the neutral axis, in N/mm^2

E_{ti} = tensile modulus of individual ply, *i*, in N/mm^2

I_i = inertia of the of individual ply, *i*, about the neutral axis, in mm^4

M_R = the appropriate Rule bending moment, as defined in Pt 5, Ch 5,5

Q_R = the appropriate Rule shear force, as defined in Pt 5, Ch 5,5

x_i = the distance to the centre of area of the individual ply, *i*, from the outer surface of the keel plate laminate, in metres

y_i = vertical distance from the hull transverse neutral axis to the centre of the individual ply, in metres

y_{NA} = the distance of the neutral axis, from the outer surface of the keel plate laminate, in metres.

$\Sigma(E_i I_i)_H$ = total $(EI)_H$ (stiffness) for the hull midship section, in Nm^4/mm^2

σ_{ci} = compressive stress within an individual element, *i*, in N/mm^2

σ_{ti} = tensile stress within an individual element, *i*, in N/mm^2

τ_H = shear stress at any position along the length of the craft, in N/mm^2

L_R and *B* are as defined in Pt 3, Ch 1,6.2.

1.2.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of raised quarterdeck craft, the strength deck is stepped as shown in Fig. 6.1.1.

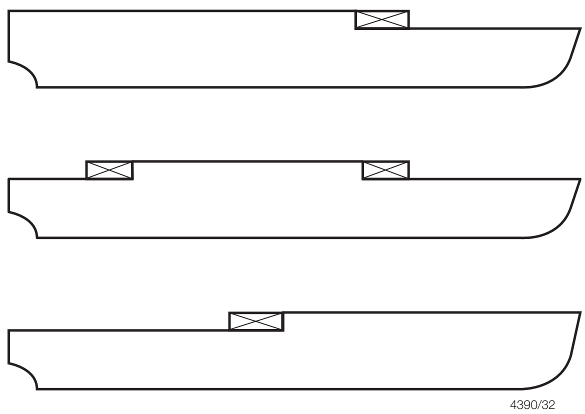


Fig. 6.1.1 Strength deck

1.3 General

1.3.1 The additional pressures arising from the influence of the global loading are considered in the determination of the longitudinal strength requirements for local and secondary stiffening and bottom shell laminate.

1.3.2 All continuous longitudinal structural material is to be included in the calculation of the stiffness, $(EI)_H$, of the hull midship section, and the lever, y_i, is to be measured vertically from the neutral axis to the centre of the individual ply, *i*. The inertia of an individual horizontal ply, *i*, about its own axes is to be ignored.

1.3.3 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performance.

1.3.4 In general, superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the craft. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations. Such calculations are to make due allowance for superstructure efficiency. *See also* Pt 7, Ch 6,2.5.

1.3.5 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull stiffness $(EI)_H$. The lever is to be taken to a position corresponding to the depth of the longitudinal member above the moulded deckline at side amidships. Each such case will be individually considered.

1.3.6 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.3.7 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements given in 2.2 are to be maintained within $0,4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0,4L_R$ part, bearing in mind the desire not to inhibit the vessel's loading and operational flexibility. L_R is as defined in 1.2.1.

1.4 Openings

1.4.1 Deck openings having a length in the fore and aft directions exceeding 0,1*B* m or a breadth exceeding 0,05*B* m, are always to be deducted from the sectional areas used in the section stiffness calculation. *B* is as defined in 1.2.1.

1.4.2 Deck openings smaller than stated in 1.4.1 including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths (*see* 1.4.3), in one transverse section does not exceed $0,06\,(B_1 - \Sigma b_1)$.
where

B_1 = breadth of craft at section considered

$\Sigma\, b_1$ = sum of breadths of deductible openings.

Where a large number of deck openings are proposed in any transverse space, special consideration will be required.

1.4.3 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in Fig. 6.1.2. The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The sections to be considered are to be perpendicular to the centreline of the ship and are to result in the maximum deduction in each transverse space.

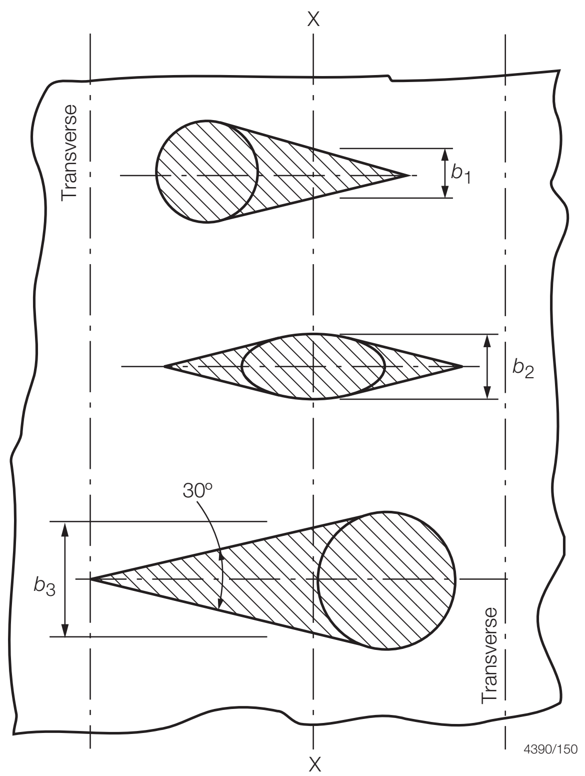
1.4.4 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm whichever is the lesser.

1.4.5 Openings are considered isolated if they are spaced not less than 1 m apart.

1.4.6 A reduction for drainage holes and scallops in beams and girders, etc., is not necessary so long as the original section stiffness at deck or keel is reduced by no more than three per cent.

1.5 Direct calculation procedure

1.5.1 In direct calculation procedures capable of deriving the wave induced loads on the ship, and hence the required modulus, account is to be taken of the ship's actual form and weight distribution.



Total equivalent breadth of small openings at XX = $b_1 + b_2 + b_3$

Fig. 6.1.2 Isolated openings

1.5.2 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.6 Approved calculation systems

1.6.1 Where the assumptions, method and procedures of a longitudinal strength calculation system have received general approval from LR, calculations using the system for a particular ship may be submitted.

1.7 Information required

1.7.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list, showing details of the volume and position of centre of gravity of all tanks and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull. A lines plan and/or Tables of offsets may also be required.

(c) Details of the calculated lightweight and its distribution.

(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions. It is recommended that this information be submitted in the form of a preliminary Loading Manual, and that it includes the calculated still water and dynamic bending moments and shear forces.

1.8 Loading guidance information

1.8.1 Sufficient information is to be supplied to the Master of every craft to enable him to arrange loading in such a way as to avoid the creation of unacceptable stresses in the craft's structure.

■ *Section 2* Hull girder strength for mono-hull craft

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 40 m, covering the range of load and ballast conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions.

2.1.2 For craft of ordinary hull form with a Rule length, L_R, less than 40 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

2.1.3 Where the Rule length, L_R, of the craft exceeds 65 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

2.2 Bending strength

2.2.1 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength. For the purposes of this analysis an element may be a deck plating, longitudinal girder, inner bottom, etc., or other continuous member.

2.2.2 The distance of the neutral axis, y_{NA}, from the outer surface of the keel plate laminate may be determined from the following:

$$y_{NA} = \frac{\Sigma\,(E_i\,a_i\,x_i)}{\Sigma\,(E_i\,a_i)_H} \text{ m}$$

2.2.3 The resultant compressive stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ci} = \frac{E_{ci}\,y_i\,M_R}{\Sigma\,(E_i\,I_i)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.4 The resultant tensile stress within an individual ply, *i*, may be determined from the following:

$$\sigma_{ti} = \frac{E_{ti}\,y_i\,M_R}{\Sigma\,(E_i\,I_i)_H} \times 10^{-3} \text{ N/mm}^2$$

2.2.5 The ultimate tensile and compressive strengths of the laminate or face reinforcement which form an element, may be determined from suitable tests or alternatively may be predicted using classical stress/strain relationships with due account being taken of the amounts of different materials and their associated strain rates to failure. In this respect materials which are incompatible in terms of their strain rates to failure are not to be mixed. Where materials are mixed the requirements of 2.2.6 for reserve factors are to be complied with when a first ply failure analysis is carried out.

2.2.6 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.3 Shear strength

2.3.1 The shear strength of the craft at any position along the length is to be examined. The shear stress, τ_H, is determined from the following:

$$\tau_H = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = effective shear area of transverse section, in m^2, to be taken as the net sectional area of the side shell plating and the longitudinal bulkheads after deductions for openings, in m^2

Q_R is as defined in 1.2.1.

2.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for ordinary mono-hulls less than 65 m in Rule length, L_R, and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering craft with unusual form or proportions, or with large deck openings. In general, calculations may be required to be carried out using a direct calculation procedure. Such calculations are to be submitted in accordance with 1.5.

Section 3
Hull girder strength for multi-hull craft

3.1 Application

3.1.1 Except as otherwise specified within this Section, the global strength requirements for multi-hull craft are to comply with Section 2.

3.1.2 Longitudinal strength calculations are to be submitted for all craft with a Rule length, L_R, exceeding 35 m, covering the range of load conditions proposed, in order to determine the required hull girder strength. Still water, static wave and dynamic bending moments and shear forces are to be calculated for both departure and arrival conditions and for any special mid-voyage conditions caused by changes in ballast distribution.

3.1.3 For craft of ordinary hull form with Rule length, L_R, less than 35 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However longitudinal strength calculations may be required at LR's discretion dependent upon the hull form, constructional arrangement and proposed loading.

3.1.4 Where the Rule length, L_R, of the craft exceeds 50 m, or for new designs of large, structurally complicated craft, the design loads and scantling determination formulae in this Chapter are to be supplemented by direct calculation and structural analysis by 3-D finite element methods. These supplementary calculations are to include the results of model tests and full scale measurement where available or required by LR. Full details of such methods and all assumptions and calculations, which are to be based on generally accepted theories, are to be submitted for appraisal.

3.1.5 The strength deck plating in way of the cross-deck structure, the wet-deck plating, longitudinal bulkheads and girders, and other continuous members may be included in the determination of the midship section stiffness.

3.1.6 Special consideration will be given to the global strength requirements for craft with more than two hulls linked by cross-deck structure.

3.2 Hull longitudinal bending strength

3.2.1 The requirements of 2.2 are to be complied with, using the appropriate design bending moment applicable to multi-hull craft, as determined from Pt 5, Ch 5,5.

3.2.2 The allowable tensile and compressive stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.3 Hull shear strength

3.3.1 The requirements of 2.3 are to be complied with in so far as they are applicable.

3.3.2 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.4 Torsional strength

3.4.1 At the discretion of LR or where a craft is of unusual form or novel construction, the torsional stress is to be determined by direct calculation methods using the twin hull torsional connecting moment as defined in Pt 5, Ch 5. Such calculations are to be submitted in accordance with 1.5.

3.5 Strength of cross-deck structures

3.5.1 Cross-deck structures are to have adequate transverse strength in relation to the design loads and moments. Generally the net areas with effective flange, after deductions of openings, are to be used for the calculations of the total stiffness of the longitudinal section of the cross-deck structures. The effective shear area of transverse strength members is the net web area after deduction of openings.

3.5.2 The twin hull transverse bending strength of the craft at any position along the length is to be examined.

3.5.3 The twin hull transverse bending stresses for both the compressive and tensile cases are to be determined by direct calculation methods, or on the basis of 2.2.3 and 2.2.4 respectively. The stresses are to be determined in conjunction with the twin hull transverse bending moment, M_R, as defined in Pt 5, Ch 5,5.

3.5.4 Due consideration is to be given to the increased bending moments which may arise due to local point loadings from pillars, fuel bunkers, heavy items of machinery, stores, etc.

3.5.5 The shear strength of the cross-deck structure is to be examined by applying the appropriate vertical shear force at the centreline of the cross-deck structure between the twin hulls. The shear stress, τ_V, is to be determined from:

$$\tau_V = \frac{Q_R}{A_\tau} \times 10^{-3} \text{ N/mm}^2$$

where

A_τ = the net cross sectional area of the primary transverse cross-deck structure, in m^2

Q_R is as defined in 1.2.1.

3.5.6 The allowable shear stress limits indicated in Table 7.3.2 in Chapter 7 are to be complied with.

3.6 Grillage structures

3.6.1 For complex girder systems, a complete structural analysis using numerical methods may be required to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended, *see also* Ch 3,4.15.

3.6.2 In general, the transverse and vertical girders, bottom and side structures, bridge structure, deck structures and any other parts of the craft which LR considers critical to the craft's structural integrity are to be included in the numerical modelling of the craft.

3.7 Analysis techniques

3.7.1 General or special purpose computer programs or any other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

3.7.2 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

3.7.3 Analysis of the cross deck structures with regard to impact loads due to slamming may have to be carried out using advanced structural analysis techniques.

Section 1
General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull craft of composite construction as defined in Ch 1,1.1.

1.2 General

1.2.1 The failure modes criteria contained within this Chapter are to be used in formulae from the preceding Chapters to determine the scantling requirements. In addition, they are to be used when direct calculations are proposed as an alternative.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate Section:

f_δ = span/deflection ratio.

1.4 Direct calculations

1.4.1 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the various failure modes.

1.5 Equivalents

1.5.1 Where direct calculations are proposed, the requirements of Pt 3, Ch 1,2 are to be complied with.

1.5.2 In addition, with the agreement of Lloyd's Register (hereinafter referred to as 'LR'), tests may be conducted to demonstrate the actual response of the structure and the results verified against the failure mode criteria in this Chapter.

Section 2
Deflection control

2.1 General

2.1.1 The requirements in respect of limiting deflection for both panels and stiffening members are given in this Section. These limits are generally based on a span/deflection ratio, f_δ, as given in Table 7.2.1, in consistent units.

Table 7.2.1 Limiting span/deflection ratio

Item	f_δ
Shell envelope:	
• sandwich construction	100
Bottom structure:	
• secondary stiffening	150
• primary girders and web frames	200
Side structure:	
• secondary stiffening	150
• primary girders and web frames	200
Main/strength deck structures:	
• sandwich construction	150
• secondary stiffening	200
• primary girders and web frames	250
• hatch covers	250
Superstructure/deckhouse laminates:	
(a) Generally: • sandwich construction	100
(b) Coachroof: • sandwich construction	150
(c) House top: • sandwich construction	100
(d) Lower/inner decks and house top subject to personnel loading:	
• sandwich construction	150
Superstructure/deckhouse stiffeners:	
(a) Generally: • secondary	100
• primary	150
(b) Coachroof: • secondary	150
• primary	200
(c) House top: • secondary	100
• primary	100
(d) Lower/inner decks and house top subject to personnel loading:	
• secondary members	150
• primary members	200
Deep tank structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	175
• primary members	200
Watertight bulkhead structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Multihull cross-deck structures:	
(a) Laminates: • sandwich construction	100
(b) Stiffeners: • secondary members	125
• primary members	150
Vehicle deck structures:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
Helicopter/flight decks:	
(a) Laminates: • sandwich construction	150
(b) Stiffeners: • secondary members	200
• primary members	250
NOTE Where significant curvature exists over the span of the stiffener or breadth of the panel, the allowable deflections will be specially considered.	

Section 3
Stress control

3.1 General

3.1.1 The nominal limiting stress for panels and primary and secondary stiffening members, subject to local and global loading conditions, are given in this Section.

3.2 Tensile and compressive stress

3.2.1 The limiting tensile and compressive stress criteria values for local and global loading conditions are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate tensile and compressive strength of the laminate at first ply failure.

3.2.2 The ultimate compressive strength of the sandwich skin laminate shall not be taken greater than the critical skin buckling stress given by

$$\sigma_{cr} = 0,5\,(E_{cps}E_{c}G)^{1/3}$$

where

σ_{cr} = critical skin buckling stress, in N/mm^2

E_c = compressive modulus of the core material, in N/mm^2

E_{cps} and G are as defined in Ch 3,1.5.1

3.3 Shear stress

3.3.1 The limiting shear stress criteria values for local and global loadings are given in Tables 7.3.1 and 7.3.2 respectively. These values are expressed as a fraction of the ultimate shear strength of the laminate.

3.4 Interlaminar shear stress

3.4.1 The interlaminar shear strength of the proposed laminate is to be demonstrated to be not less than 13,8 N/mm^2.

3.5 Core shear stress

3.5.1 The limiting core shear stress criteria values are given in Table 7.3.3. These values are expressed as a fraction of the ultimate core shear strength of the core material, *see also* Ch 3,1.13.9.

3.5.2 The ultimate core shear strength of the core material is to be taken as 90 per cent of the mean ultimate shear strength determined from accepted mechanical tests, or the mean minus two standard deviations based on a minimum of five samples, whichever is less. All test pieces are to be representative of the product to be manufactured and details are to be submitted for consideration.

Table 7.3.1 Limiting stress criteria for local loading (*see continuation*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Shell envelope:			
(a) Bottom shell laminate:			
• slamming zone	0,28	0,28	—
• elsewhere	0,25	0,25	—
(b) Side shell laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(c) Keel	0,25	0,25	—
Bottom structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
(c) Engine girders	0,33	0,33	0,33
Side structure:			
(a) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(b) Primary girders and web frames	0,33	0,33	0,33
Main/strength deck laminate and stiffeners:			
(a) Laminate	0,30	0,30	—
(b) Secondary stiffening	0,30	0,30	0,30
(c) Primary girders and web frames	0,33	0,33	0,33
(d) Hatch covers	0,25	0,25	0,25
Superstructures/deckhouses:			
(a) Deckhouse front, 1st tier:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(b) Deckhouse front, upper tiers:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(c) Deckhouse, aft and sides:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(d) Coachroof:			
• laminate	0,30	0,30	—
• stiffening	0,33	0,33	0,33
(e) House top, not subject to personnel loading:			
• laminate	0,40	0,40	—
• stiffening	0,40	0,40	0,40
(f) Lower/inner decks and house top, subject to personnel loading:			
• laminate	0,33	0,33	—
• stiffening	0,30	0,30	0,30

3.5.3 In the absence of suitable test data, LR will consider basing the ultimate core shear strength on manufacturer recommended minimum design values based on mechanical tests performed by the core material manufacturer using accepted test methods.

Table 7.3.1 Limiting stress criteria for local loading (*conclusion*)

Item	Limiting stress fraction		
	Tensile	Compressive	Shear
Bulkheads:			
(a) Collision bulkhead:			
• laminate	0,26	0,26	—
• secondary stiffening	0,32	0,32	0,32
• primary stiffening	0,32	0,32	0,32
(b) Watertight bulkhead:			
• laminate	0,33	0,33	—
• secondary stiffening	0,40	0,40	0,40
• primary stiffening	0,40	0,40	0,40
(c) Watertight bulkhead doors:			
• in collision bulkhead	0,25	0,25	—
• in other bulkheads	0,33	0,33	—
(d) Structure supporting watertight doors:			
• in collision bulkhead	0,25	0,25	0,25
• in other bulkheads	0,33	0,33	0,33
(e) Minor bulkheads:			
• laminate	0,50	0,50	—
• secondary stiffening	0,50	0,50	0,50
• primary stiffening	0,50	0,50	0,50
(f) Deep tank bulkheads:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
Multihull cross-deck structure:			
(a) Laminate:			
• slamming zone	0,33	0,33	—
• elsewhere	0,30	0,30	—
(b) Secondary stiffening:			
• slamming zone	0,33	0,33	0,33
• elsewhere	0,30	0,30	0,30
(c) Primary stiffening	0,33	0,33	0,33
Vehicle deck:			
(a) Laminate	0,25	0,25	—
(b) Secondary stiffening	0,33	0,33	0,33
(c) Primary stiffening	0,33	0,33	0,33
Helicopter/flight decks:			
(a) Normal usage:			
• laminate	0,25	0,25	—
• secondary stiffening	0,33	0,33	0,33
• primary stiffening	0,33	0,33	0,33
(b) Emergency landing:			
• laminate	0,33	0,33	—
• secondary stiffening	0,43	0,43	0,43
• primary stiffening	0,43	0,43	0,43

Table 7.3.2 Limiting stress criteria for global loading

Operational mode of craft	Limiting stress fraction			
	Tensile	Compressive	Shear *see* Note 1	Shear *see* Note 2
$\Gamma \geq 3{,}0$ or $\Delta \leq 0{,}04(L_R\ B)^{1{,}5}$	0,33	0,33	0,33	0,33
$\Gamma < 3{,}0$ and $\Delta > 0{,}04(L_R\ B)^{1{,}5}$	0,25	0,25	0,25	0,25

NOTES
1. Limiting stress fraction for the hull shear stress at any point along the craft length.
2. Limiting stress fraction for the vertical shear stress for the cross-deck structure.

Δ is the displacement as defined in Pt 5, Ch 2,2.
Γ is the Taylor Quotient as defined in Pt 5, Ch 2,2.1.16.
L_R and B are as defined in Pt 3, Ch 1,6.2.

Table 7.3.3 Limiting core shear stress criteria

Core Material	Limiting shear stress fraction
PVC	0,45
All other cores	0,35

■ *Section 4*
Buckling control

4.1 General

4.1.1 The requirements in respect of the control of buckling of single skin and sandwich panels, including global buckling of structures, pillars and pillar bulkheads are given in this Section.

4.2 Single skin laminate

4.2.1 Where single skin laminate panels are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3 Sandwich skin laminate

4.3.1 Where sandwich panel skin laminates are subject to compressive loading likely to cause axial buckling, design calculations are to be submitted indicating the margin against failure.

4.3.2 Where sandwich panels subject to compressive loading have skin thicknesses which are less than the minimum required by Ch 3,2.3, design calculations are to be submitted indicating the margin against failure due to wrinkling of the sandwich skin laminates.

4.3.3 Where production methods or the craft design gives rise to local distortion or irregularity of the sandwich, the designer is to make due allowance for the reduction in critical wrinkling stress.

4.4 Pillars and pillar bulkheads

4.4.1 In general, the requirements in respect of the control of buckling of pillars and pillar bulkheads are given in Ch 3,10.

■ *Section 5*
Impact control

5.1 General

5.1.1 Skin thicknesses may be accepted which are below the stated Rule minima indicated throughout the Rules provided that acceptable stress levels are predicted for the in service condition and that equivalent impact strength can be demonstrated to the satisfaction of LR. In such cases due consideration is to be given to providing a satisfactory water barrier and ensuring suitability to resist abrasion, local point loadings, etc., *see* Ch 3,2.

5.2 Testing

5.2.1 All impact tests are to be comparative tests using the Rule basic laminate as the comparative standard. Original and tested samples of both the proposed laminate and the Rule comparison laminate are to be submitted for LR's consideration together with a detailed test report. Testing is to be carried out by the Builder and witnessed by the LR Surveyor or at an independent testing establishment, acceptable to LR. Comparison will be by visual inspection only and interpretation of the results will be at the sole discretion of LR.

Section 6
Temperature control of cored sandwich structures

6.1 General

6.1.1 Where foam core materials are used in sandwich construction the properties at elevated temperature are to be considered. Where appropriate the mechanical properties are to be those at the maximum ambient temperature expected under normal operating conditions.

6.1.2 Alternatively other methods of controlling the temperature of the core may be considered, e.g. inserts, insulation.

6.2 Information required

6.2.1 The source of the mechanical properties data is to be shown on the Materials Data Sheet (Form 2075) when the plans are initially submitted for approval.

6.2.2 Test data is to be submitted for each grade of foam core in respect of:

- Core shear strength.
- Core shear modulus.
- Tensile strength
  (only for high density cores, i.e. > 100 kg/m^3).
- Tensile modulus
  (only for high density cores, i.e. > 100 kg/m^3).

6.3 Testing

6.3.1 Core materials are to be tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials*.

6.4 National Authority requirements

6.4.1 National Authority requirements are to be complied with as applicable.

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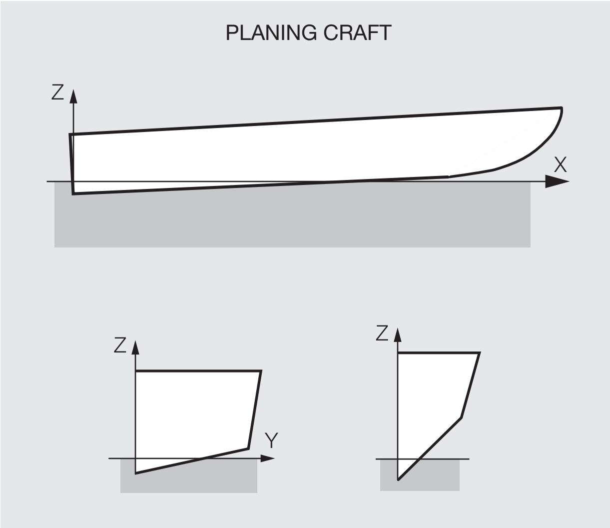
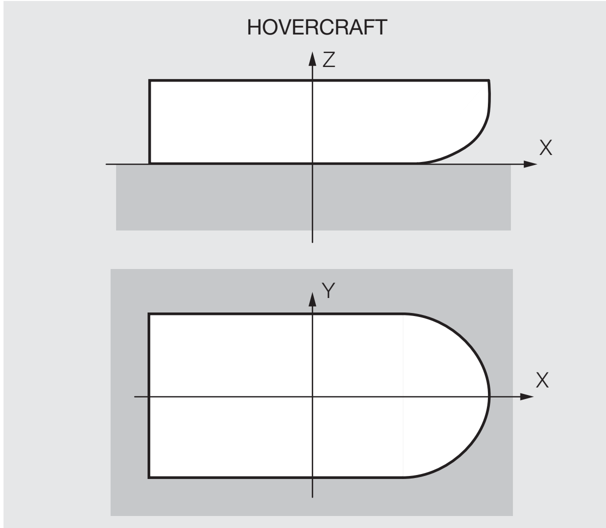
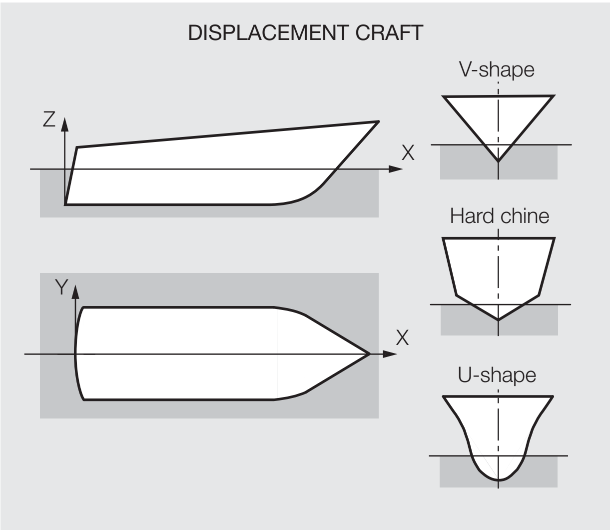
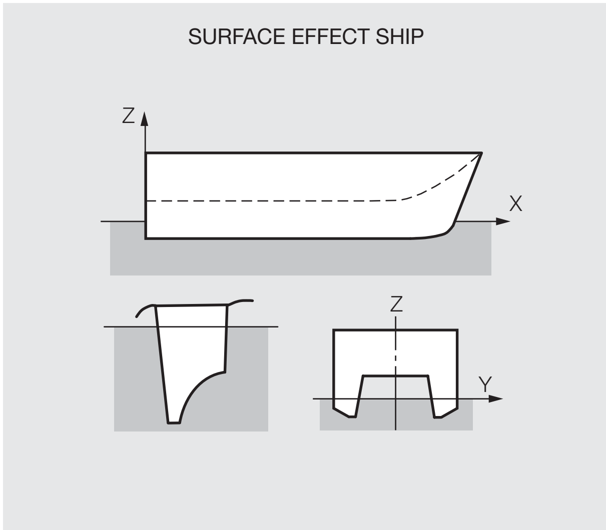
LIFE MATTERS

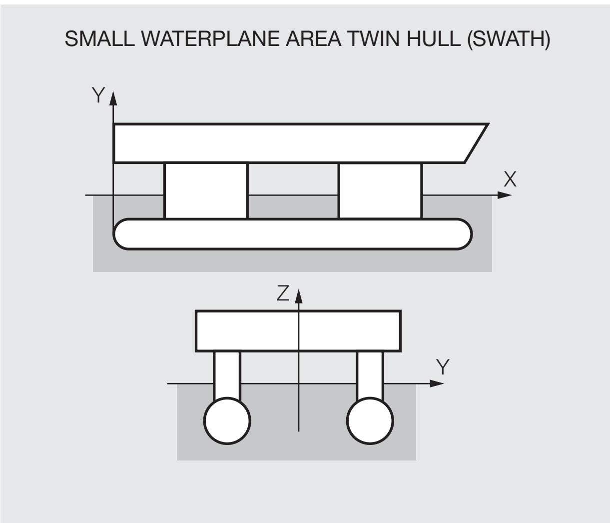
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

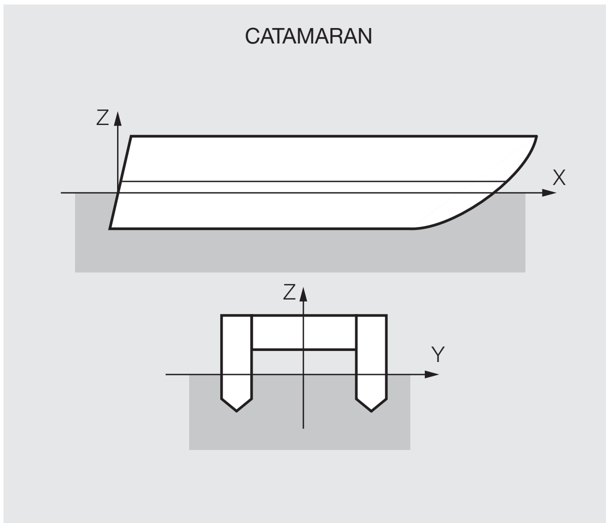




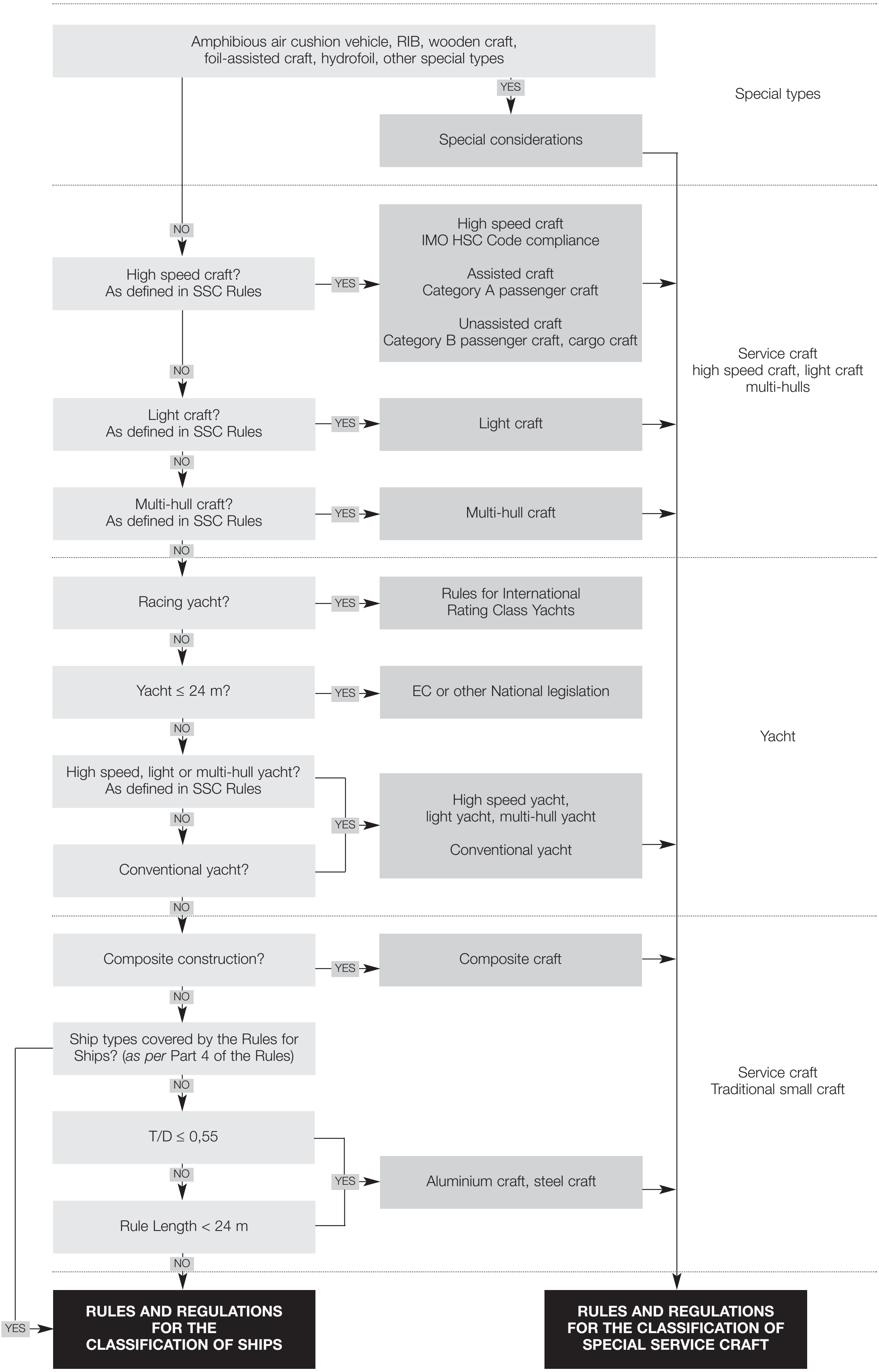








DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



Rules and Regulations for the Classification of Special Service Craft

Volume 7
Part 9
General Requirements for Machinery
July 2012

LIFE MATTERS

Chapter Contents Part 9

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■ *Section 1* General requirements

1.1 Application

1.1.1 Parts 9 to 16 apply to the design, construction, installation and testing of:

- Main propulsion machinery systems
- Essential auxiliary machinery systems, excluding the crankshaft for diesel engines intended for essential services where power does not exceed 110 kW
- Steering and manoeuvring systems

together with their associated equipment, pressure plant, piping systems, control engineering and electrical engineering systems for the craft types stated in Pt 1, Ch 2,1.

1.1.2 The Rules incorporate those requirements of the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74) Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*) hereinafter referred to as the HSC code, as applicable to the classification of such craft.

1.1.3 Requirements for craft which are not required to comply with the IMO Code for High Speed Craft are given at the end of each Chapter. Requirements for service craft, yachts of 24 m or greater and other craft types have been included in these requirements. For the purposes of Parts 9 to 16, small craft are service craft of less than 24 m in length.

1.1.4 Special requirements are included for main and auxiliary machinery, pumping and piping, electrical and control engineering and fire extinction for yachts that are 500 gt or more.

1.1.5 These Rules are applicable to machinery systems burning distillate fuels which do not require to be heated.

1.2 General

1.2.1 The units and formulae used in the Rules are in SI Units.

1.2.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the information required is prepared and submitted.

1.2.3 Where the craft is defined as a Passenger (B) Craft (*see* Pt 1, Ch 2,3), sufficient redundancy is to be provided such that in the event of damage to any part of a main propulsion drive system, the craft is able to maintain sufficient seaway.

1.2.4 Sufficient astern power is to be provided to maintain control of the craft in all normal circumstances.

1.2.5 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed, required to achieve the maximum craft velocity at the certified maximum operational weight in smooth water.

1.2.6 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short term high power operation) in conjunction with the intended operation service profile.

1.2.7 Provision shall be made to facilitate cleaning, inspection and mantenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

1.3 Fuel flash point

1.3.1 The flash point (closed cup test) of oil fuel is in general to be not less than 60°C. For emergency generator engines a flash point of not less than 43°C is permissible.

1.3.2 Oil fuel with a flash point lower than 60°C may be used where it can be shown that the temperature of the oil fuel will always be not less than 10°C below its flash point.

1.3.3 The use of fuel with a flash point below 43°C is not recommended. However, fuel with a lower flash point , but not lower than 35°C, may be used in gas turbines only, subject to compliance with the provisions in Section 4.

1.4 Exhaust

1.4.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220ºC, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

1.5 Bearings

1.5.1 Roller element bearings are to have an L10 design life of at least 30 000 hours, based upon the design operating conditions, including short term high power operation. An L10 design life of less than 30 000 hours would be accepted, provided it is proposed in conjunction with the manufacturer's design/maintenance manual.

1.6 Vibration of shaft systems

1.6.1 The Shipbuilders are to ensure that the systems are free from excessive vibrations, excessive bearing reactions and excessive bending moments under all design operating conditions.

1.6.2 Where changes are subsequently made to a dynamic system which has been approved by Lloyd's Register (hereinafter referred to as 'LR'), e.g. machining a shaft, fitting a propeller of a different design to the working propeller or fitting a different flexible coupling, full details of the changes are to be advised. Revised calculations may be required to be submitted.

1.6.3 Where there is experience of previous similar systems which have been approved, full details of these installations may be submitted for consideration in lieu of calculations.

1.7 Alternative system of survey

1.7.1 Where items of machinery are manufactured as individual or series produced units, LR will give consideration to the adoption of a survey procedure based upon an approved quality assurance system to ISO 9001 (or equivalent) utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual components.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of plans, information and specifications as listed are to be submitted before commencement of manufacture.

2.2 Plans

2.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

2.2.2 Individual Chapters also list plans to be submitted for specific machinery systems or components.

2.2.3 Where machinery system components have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or service, plans of the components will not be required to be submitted for individual newbuildings. Full details of the components are to be advised.

2.2.4 Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type, and design of mounts.

2.2.5 The plans of arrangement of resin chocks for machinery requiring accurate alignment are to be submitted.

2.3 Calculations and specifications

2.3.1 Relevant data covering the following topics is to be submitted.

2.3.2 **Service Profile.** The machinery power/speed operational envelope indicating all the intended operational points applicable to the class notation, and any short term high power operation.

2.3.3 **Classification rating**:

(a) The following operational parameters are to be taken, using the design conditions for the intended Class Notation:
- Total barometric pressure, in bar.
- Temperature of engine room, or suction air, in °C.
- The relative humidity, in per cent.
- Temperature of sea water, or charge air coolant inlet, in °C.

(b) For unrestricted service, the following operational parameters ambient reference conditions are to be taken:
- Total barometric pressure, at 1000 mb.
- Temperature of engine room or suction air, at 45°C.
- Relative humidity, at 60 per cent.
- Temperature of sea water or charge air coolant inlet, at 32°C.

2.3.4 **Short term high power operation**. Where the propulsion machinery is being considered for short term high power operation, full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller:

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.

(b) Excessive overload may require the interval between surveys to be reduced.

(c) Machinery is to be maintained in accordance with the manufacturers' requirements.

2.3.5 **Damper and Flexible Coupling characteristics**. Documentary evidence that the characteristics have been verified.

2.3.6 **Machinery Fastening**.

(a) Documentary evidence and calculations indicating that machinery is securely mounted for the accelerations to be expected during service.

(b) Calculations that mountings of large masses such as main engines, auxiliary engines, lift fans and electrical equipment can withstand the design collision acceleration according to 5.2.1 without fracturing.

(c) Natural frequency calculation of resilient mounted machinery.

(d) For non-metallic machinery chocks:

   (i) Resin type.

   (ii) The effective area and minimum thickness of the chocks.

   (iii) The total deadweight loading of machinery.

   (iv) The thrust load, where applicable, that will be applied to the chocked item.

   (v) The loading to be applied to the holding-down bolts.

   (vi) The material of the holding-down bolts.

   (vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

2.3.7 **Manuals**. The operation and maintenance manuals.

2.3.8 **Failure Mode and Effect Analysis**. Where required for high speed craft, an FMEA is to be carried out covering the following systems:

(a) Main and auxiliary machinery systems, and their controls.

(b) Steering systems.

(c) Electrical systems.

2.3.9 **Fatigue Strength Analysis**. Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

■ *Section 3*
Certification of materials

3.1 Materials of construction

3.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Details of all materials included and not included in the Rules for Materials are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

3.1.2 Materials used in the construction of machinery and its installation are not to contain asbestos.

■ *Section 4*
Operating conditions

4.1 Machinery control

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board, without external aid, so that the operating conditions for which the craft is classed, can be maintained.

4.2 Inclinations of the craft

4.2.1 The main and auxiliary machinery is to be designed and installed such that it operates satisfactorily under the conditions as shown in Table 1.4.1.

Table 1.4.1 Inclinations

Installations, components	Angle of inclination, degrees, *see* Note 1			
	Athwartship		Fore-and-aft	
	Static	Dynamic	Static	Dynamic
Main and auxiliary machinery essential to the propulsion and safety of the craft	15	22,5	5 *see* Note 2	7,5
Emergency machinery and equipment fitted in accordance with Statutory Requirements	22,5	22,5	10	10

NOTES
1. Athwartships and fore-and-aft inclination may occur simultaneously.
2. Where the length of the craft exceeds 100 m, the fore-and-aft static angle of inclination may be taken as:

$$\frac{500}{L_{WL}} \text{ degrees}$$

where
L_{WL} = craft waterline length, in metres

4.2.2 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the craft inclined under the conditions as shown in Table 1.4.1.

4.2.3 Deviations from these conditions may be accepted taking into consideration type and size of the craft and the class notation. The Shipbuilder is to ensure that the main and auxiliary machinery is capable of operating at the proposed angles of inclination.

4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, *P*, in kW (*H*, in shp), and revolutions per minute, *R*, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient operating conditions

4.4.1 Main and essential auxiliary machinery and equipment is to be capable of operating satisfactorily under the conditions shown in Table 1.4.2.

Table 1.4.2 Ambient operating conditions

Air		
Installations, Components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery components, boilers. In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)
Sea-water or charge air coolant inlet to charge air cooler		-2 to +32, *see* Notes 1 and 3

NOTES
1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.
2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*
3. Charge air cooling arrangements utilising re-circulated cooling to maintain temperatures in a different range are accepted where the machinery and equipment operation is not degraded with a primary supply of cooling in the temperature range stated in this Table.

4.4.2 Where it is intended to allow for operation in ambient temperatures outside those shown in Table 1.4.2, the permissible temperatures and associated periods of time are to be specified and details are to be submitted for consideration. Propelling and essential auxiliary machinery, *see* Pt 1, Ch 2, 3.10.1, is to retain a continuous level of functional capability under these conditions and any level of degraded performance is to be defined. Operation under these circumstances is not to be the cause of damage to equipment in the system and is additionally to be acceptable to the National Authority of the country in which the craft is to be registered

■ *Section 5* Securing of machinery

5.1 Fastenings

5.1.1 Bedplates, thrust seatings and other fastenings are to be of robust construction. The machinery is to be securely fixed to the craft's structure, such that the arrangement is sufficient to restrain the dynamic forces arising from vertical and horizontal acceleration appropriate to the intended service.

5.2 Collision load

5.2.1 Unless an accurate analysis of the collision load is submitted and found acceptable by LR, the collision load is to be determined from:

$$g(\text{collision}) = 1{,}2\,\frac{P_{coll}}{\Delta g}$$

where the load P_{coll} is taken as the lesser of:

P_{coll} = $460\,(M\,C_L)^{2/3}\quad(E\,C_H)^{1/3}$ kN

P_{coll} = $9000\,M\,C_L\;[C_H\,(T+2)]^{1/2}$ kN

where

C_H = a factor given in Table 1.5.1

C_L = $\dfrac{(165+L_{WL})}{245}\left(\dfrac{L_{WL}}{80}\right)^{0,4}$

D = craft depth, in metres, from the underside of keel amidships to the top of effective hull girder

E = $0{,}5\Delta\,V^2$ kNm

H_T = minimum height, in metres, from tunnel or wet-deck bottom to the top of effective hull girder for catamarans and surface effect ships
= D for air cushion vehicles

L_{WL} = craft waterline length, in metres

M = 1,3 for high tensile steel
= 1,0 for aluminium alloy
= 0,95 for mild steel
= 0,8 for fibre reinforced plastics

T = buoyancy tank clearance to skirt tip, in metres, (negative) for ACVs
= lifted clearance from keel to water surface, in metres, (negative) for hydrofoils
= craft draught to the underside of keel amidships, in metres, for all other craft

V = operational speed of craft, in m/s

g = gravitational acceleration = 9,806 m/s^2
Δ = craft displacement, to be taken as the mean of the lightweight and maximum operational weight, in tonnes.

Table 1.5.1 Factor C_H

Factor, C_H	Catamarans, SES	Mono-hulls, H Foils	ACVs
C_H	$\dfrac{T + 2 + f(D/2)}{2D}$	$\dfrac{T + 2 + f(D/2)}{2D}$	$\dfrac{f}{4}$
where f = 0 for f = 1 for f = 2 for	 $T + 2 < D - H_T$ $D > T + 2 \geq D - H_T$ $T + 2 \geq DM$	 $T + 2 < D$ $T + 2 \geq D$ —	 — $H_T > 2$ $H_T \leq 2$

5.3 Resilient mounts

5.3.1 Creep of rubber mounts and the effects on the alignment are also to be considered.

5.3.2 Shafting, piping connections and electrical cable connections are to be provided with sufficient flexibility to accommodate such movements. Particular attention should be paid to exhaust bellows and the effectiveness of flexible couplings.

5.3.3 Limit stops are to be fitted as necessary to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate propeller thrust.

5.3.4 Mounts are to be shielded from the possible detrimental effects of oil.

5.4 Machinery mounted on resin chocks

5.4.1 These Rules relate to the application of synthetic resin compounds as materials for chocks under machinery components where accurate alignments are important, e.g. main engine, gearbox and auxiliary installations where the engine and generator do not share a common baseplate.

5.4.2 Resin compounds used in these applications are to be of a type accepted by LR.

5.4.3 The use of resin for chocking gas turbine casings or similar high temperature applications will not be considered.

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 Plans and particulars

6.1.1 At least three copies of the following plans are to be submitted for approval at the earliest opportunity:

- Crankshaft including details of the material specification.
- Gearing including details of the material specification.
- Arrangement and details of the propulsion shafting, couplings and bearing disposition, etc.
- Propeller where the diameter exceeds 1 m.
- Diagrammatic arrangements of the exhaust systems indicating the materials, methods of cooling, and if water spray is injected, the method of draining.
- Starting air system and receivers.
- Diagrammatic arrangements of pumping and piping systems including the air and sounding pipes for the tanks.
- Diagrammatic arrangements of bilge and fire water pumps and piping for craft having a Rules length of 12 m and over and which are subdivided into watertight compartments.
- Diagrammatic arrangement of oil fuel piping.
- Construction arrangements of separate oil fuel tanks having a capacity exceeding 250 litres.
- Electrical equipment as detailed in Pt 16, Ch 2.
- Steering gear machinery and hydraulic circuit diagram if applicable.
- Fire extinction equipment as detailed in Part 17.
- Safety plan showing the position of all fire prevention controls, fixed and loose equipment and portable extinguishers, *see* Pt 17, Ch 1 to 4.
- Control circuits and alarm points as detailed in Pt 16, Ch 1.

6.1.2 The following particulars are to be submitted with the plans of crankshaft, gearbox or shafting as applicable:

- Name of manufacturer.
- Type designation.
- Particulars of engine cycle.
- Number of cylinders and vee angle where applicable.
- Maximum combustion pressure and mean indicated pressure.
- Span of bearings adjacent to a crank measured from centreline of the bearing to the centreline of the adjacent bearing.
- Proposed shaft power (kW) and revolutions per minute of the engine at each operating condition.
- Gear box reduction ratio.
- For engines over 500 kW, *see* Pt 10, Ch 1,3.

6.1.3 Where machinery system components or equipment have been approved under LR's Type Approval System or Machinery General Design Appraisal for the proposed design conditions or intended service, full details of the components should be advised to enable the validity of the approval to be checked. In cases where valid approvals are confirmed, plans are not required to be submitted for approval for individual craft.

6.2 Calculations

6.2.1 Design calculations are to be submitted for the following systems and conditions:

(a) Direct calculation for design strength of machinery supports, such as engine mountings, on craft subjected to high accelerations, *see* Section 5.

(b) Calculations of torsional vibrations for main engines where the power exceeds 500 kW and for auxiliary engines for essential services where the power exceeds 110 kW.

6.3 Certification of materials

6.3.1 The requirements of 3.1 apply to all types of craft.

6.3.2 Where no provision is made in these Rules, materials may be accepted provided that they comply with an approved specification and such tests as may be considered necessary by the Surveyor.

6.3.3 The requirements for materials for machinery components are indicated in the relevant Part or Chapter of the Rules.

6.4 Operating conditions

6.4.1 The requirements of 4.2 do not apply to yachts or service craft less than 24 m.

6.4.2 For patrol craft and high speed craft of 24 m or greater, the main and auxiliary machinery is to be designed to operate under the conditions defined in Sections 4 and 5.

6.4.3 If operation under the required accelerations cannot be demonstrated on trials, alternative documentary evidence is to be presented to confirm that the machinery is capable of operating under such conditions.

6.4.4 Additional trials or conditions may be imposed to prove the machinery as considered necessary.

6.5 Securing of machinery

6.5.1 The requirements of 5.1, 5.3 and 5.4 apply.

6.5.2 Engines are to be installed so as to permit easy access to fittings, such as lubricating oil connections, bilge suctions and sea cocks.

6.5.3 Where the hull is constructed of FRP, wood or composites, and the hull surfaces are not adequately protected against oil contamination, drip trays are to be fitted under those parts of the engine and gearbox where leakage of oil fuel or lubricating oil might occur. Means are to be provided for removing any leakage easily.

6.5.4 Where resilient mounts are fitted, the name of the manufacturer and details of the type of mounting are to be indicated on the plan of the shafting.

6.5.5 Where inclinations beyond those defined in 4.2 might be experienced, such as yacht roll over, means are to be provided to prevent machinery becoming dislodged.

6.5.6 Satisfactory arrangements are to be made to transmit the propulsion thrust into the craft structure.

6.6 Ventilation of machinery spaces

6.6.1 For yachts and service craft of less than 24 m the ventilation of the machinery space is to be adequate for all conditions of the operation of the machinery and in no case is to be less than that required by the engine manufacturer.

6.6.2 The engine compartment is to be provided with inlet and outlet ventilating ducts. One or more inlet ducts are to extend down to a suitable low level.

6.6.3 Outlet ducts are to be connected near or at the top of the compartment and are to be arranged for natural or mechanical extraction as necessary.

6.6.4 Consideration will be given to equivalent alternative arrangements provided full details are submitted before construction is commenced.

Section 1
General requirements

1.1 Surveys during construction

1.1.1 Machinery is to be surveyed at the manufacturer's works from the commencement of work until the final test under working conditions. The Surveyors are to be satisfied that the materials, workmanship and arrangements are satisfactory and in accordance with the Rules.

1.1.2 Lloyd's Register's (hereinafter referred to as LR) requirements for the conditions of manufacture, survey and certification of materials used for the production of forged steel and castings used in the production of components are given in *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

1.2 Miscellaneous surveys

1.2.1 Resilient mounts are to be installed under survey and the machinery tested under full working conditions.

1.2.2 Alignment of machinery is to be checked after the first six months of operation.

Section 2
Diesel engines

2.1 Construction and welding

2.1.1 Welding of engine structures is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.1.2 On completion of welding and stress relief heat treatment, welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method. Other joints are to be similarly tested if required by the Surveyors.

2.1.3 Forgings and castings are to be examined at the manufacturer's works.

2.2 Hydraulic testing

2.2.1 Items are to be tested by hydraulic pressure as indicated in Table 2.2.1.

2.3 Non-destructive testing

2.3.1 Non-destructive examination of welded construction is to be conducted in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

2.4 Engine type testing

2.4.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

2.4.2 Guidelines for type testing of engines will be supplied on application.

2.4.3 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see* Pt 10, Ch 1,2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

2.4.4 An engine type is defined in terms of:
- Basic engine data, e.g. bore, stroke.
- Working cycle; 2 stroke, 4 stroke.
- Cylinder arrangement; in-line, vee.
- Cylinder rating.
- Fuel supply, e.g. direct or indirect injection.
- Gas exchange; natural aspiration, pressure charging arrangement.

2.4.5 Where an engine type has subsequently proved satisfactory in service with a number of applications a maximum uprating of 10 per cent may be considered without a further complete type test.

Table 2.2.1 Test pressures

Item	Test pressure
Fuel injection system: Pump body, pressure side; Valve; Pipe	The lesser of 1,5p or p + 295 bar
Cylinder cover, cooling space Cylinder liner, over the whole length of cooling space Piston crown, cooling space (where piston rod seals cooling space, test after assembly)	7,0 bar
Cylinder jacket, cooling space Exhaust valve, cooling space Turbo-charger, cooling space Exhaust pipe, cooling space Coolers, each side Engine driven pumps (oil, water, fuel, bilge)	The greater of 4,0 bar or 1,5p
Air compressor, including cylinders, covers, intercoolers and aftercoolers	Air side: 1,5p Water side: The greater of 4,0 bar or 1,5p
Scavenge pump cylinder	4,0 bar

NOTES
1. p is the maximum working pressure, in bar, in the item concerned.
2. Fuel pumps of the jerk or timed pump system are not included.
3. Turbo-charger air coolers need only be tested on the water side.
4. For forged steel cylinder covers alternative testing methods will be specially considered.

2.4.6 A type test will be considered to cover engines of a given design for a range of cylinder numbers in a given cylinder arrangement.

■ *Section 3* Turbo-chargers

3.1 Type testing

3.1.1 A type test is to consist of a hot gas running test of at least one hour duration at the maximum permissible speed and maximum permissible temperature. Following the test the turbo-charger is to be completely dismantled for examination of all parts.

3.1.2 Alternative arrangements will be considered.

3.2 Dynamic balancing

3.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

3.3 Overspeed tests

3.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature.

3.4 Mechanical running tests

3.4.1 Turbo-chargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

3.4.2 Upon application, with details of an historical audit covering previous testing of turbo-chargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test to a representative sample of turbo-chargers.

■ *Section 4* Gas turbines

4.1 Dynamic balancing

4.1.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

4.2 Hydraulic testing

4.2.1 All casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure.

4.2.2 Where hydraulic tests cannot be carried out on the casing, alternative proposals will be considered.

4.2.3 Intercoolers and heat exchangers are to be tested to 1,5 times the maximum working pressure on each side separately.

4.3 Overspeed tests

4.3.1 Before installation, the gas turbine is to be tested for five minutes at five per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

4.3.2 Where it is impracticable to overspeed the complete installation, each rotor, completely bladed and with all relevant parts such as half-couplings, is to be overspeed-tested individually at the appropriate speed.

■ *Section 5* Gearing

5.1 Construction and welding

5.1.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

5.1.2 Where welded construction is used for the manufacture of wheels and gearcases, welding is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.1.3 Welded constructions are to be stress relief heat treated on completion of welding.

5.1.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

5.2 Accuracy of gear cutting

5.2.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose records of measurements are to be available for review.

5.3 Non-destructive testing

5.3.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

5.3.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

5.3.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth to core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

5.4 Dynamic balancing

5.4.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

5.4.2 The permissible residual unbalance, U, is defined as follows:

$$U = \frac{60m}{R} \times 10^3 \text{ g mm} \quad \text{for } R \leq 3000$$

$$U = \frac{24m}{R} \times 10^3 \text{ g mm} \quad \text{for } R > 3000$$

where

m = mass of rotating element, in kg

R = maximum service rev/min of the rotating element.

5.4.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

5.5 Meshing tests

5.5.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

5.5.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

5.5.3 For gears without crowning or helix correction the marking is to be not less than shown in Table 2.5.1.

5.5.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

Table 2.5.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \leq 5$ $Q \geq 6$	50% b x 40% h_w + 40% b x 20% h_w 35% b x 40% h_w + 35% b x 20% h_w

NOTES
1. Where b is the face width and h_w is the working tooth depth.
2. For spur gears, the values of h_w should be increased by a further 10%.

5.5.5 For gears with crowning or helix correction, the marking is to correspond to the designed no load contact pattern.

5.5.6 A permanent record is to be made of the meshing contact for the purpose of checking the alignment when installed on board the craft.

5.5.7 The full load tooth contact marking is to be not less than shown in Table 2.5.2.

Table 2.5.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
$Q \leq 5$ $Q \geq 6$	60% b x 70% h_w + 30% b x 50% h_w 45% b x 60% h_w + 35% b x 40% h_w

NOTES
1. Where b is the face width and h_w is the working tooth depth.
2. For spur gears, the values of h_w should be increased by a further 10%.

5.5.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

5.5.9 The normal backlash between any pair of gears should not be less than:

$$\frac{a\,\alpha_n}{90000} + 0{,}1 \text{ mm}$$

where
α_n = normal pressure angle, in degrees
a = centre distance, in mm.

Section 6 Shafting systems

6.1 Construction and installation

6.1.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

6.1.2 Before boring the sternframe the structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

Section 7 Propellers

7.1 Construction and welding

7.1.1 Castings are to be examined at the manufacturer's works.

7.1.2 All finished propellers are to be examined for material defects and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of Ch 9,1 of the Rules for Materials.

7.2 Shop tests of keyless propellers

7.2.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

7.2.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

7.3 Shop tests of controllable pitch propellers

7.3.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

7.3.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

7.4 Final fitting of keyless propellers

7.4.1 After verifying that the propeller and shaft are at the same temperature and the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

7.4.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

7.4.3 The outside of the propeller boss is to be hard stamped with the following details:

- For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0°C and 35°C, in mm.
- For the dry fitting method, the push-up load at 0°C and 35°C, in Newtons.

7.4.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

7.5 Final fitting of keyed propellers

7.5.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

Section 8
Water jet units

8.1 Construction and welding

8.1.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

8.1.2 Welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

8.1.3 Welded components are to comply with the requirements of Pt 15, Ch 4 and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

8.2 Testing

8.2.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

8.2.2 Upon completion, the impeller assembly is to be suitably balanced in accordance with ISO 940 Grade G6,3 or an equivalent Standard.

Section 9
Thrusters

9.1 Azimuth thrusters

9.1.1 The performance specified for the craft is to be demonstrated.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.2 Tunnel thrusters

9.2.1 It is to be demonstrated that the thruster unit meets the specified performance.

Section 10
Steering systems

10.1 Construction

10.1.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

10.2 Type testing

10.2.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

10.3 Testing

10.3.1 After installation on board the craft the steering unit is to be subjected to the applicable hydrostatic and running tests.

10.3.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.
(b) The steering power units, including transfer between steering power units.
(c) The isolation of one power actuating system, checking the time for regaining steering capability.

(d) The hydraulic fluid recharging system (may be effected at the dockside).
(e) The emergency power supply.
(f) The steering controls, including transfer of control and local control.
(g) The means of communication between the steering compartment and the wheelhouse, also the engine room, if applicable (may be effected at the dockside).
(h) The alarms and indicators (may be effected at the dockside).
(j) Where the steering system is designed to avoid hydraulic locking this feature is to be demonstrated (may be effected at the dockside).

Section 11
Sea trials

11.1 Sea trials requirements

11.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

11.2 Programme

11.2.1 Sea trials are to include the demonstration of:
(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.
(b) The effectiveness of the steering gear control systems.
(c) Manoeuvring, to include:
- starting;
- normal and emergency stopping;
- reversing;
- governor testing;
- safety devices, and associated indicators and alarms.

(d) The redundancy arrangements for Category B craft.
(e) Tooth contact markings in geared installations using a recognised technique. The marking is to be as detailed in 5.5.
(f) For controllable pitch propellers, the pitch setting under failure conditions.

11.3 Performance testing

11.3.1 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

11.3.2 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

11.3.3 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

11.3.4 Overloading of machinery is not to occur under continuous astern power.

Rules and Regulations for the Classification of Special Service Craft

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Part 10

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Lloyd's Register

LIFE MATTERS

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■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of Section 4 do not apply to diesel engines intended for essential services where power does not exceed 110 kW.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary diesel engines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.5 Engine type testing

1.5.1 Engines are to be subjected to type testing in accordance with Pt 9, Ch 2,2.4.

■ *Section 2* Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted for consideration:

- Crankshaft assembly plan (for each crank-throw).
- Crankshaft details plan (for each crank-throw).
- Thrust shaft or intermediate shaft (if integral with engine).
- Output shaft coupling bolts.
- Main engine securing arrangements where non-metallic chocks are used.
- Type and arrangement of crankcase explosion relief valves.
- Arrangement and welding specifications with details of the procedures for fabricated bedplate, thrust bearing bedplate, crankcases, frames and entablatures. Details of materials, welding consumables, fit-up conditions, fabrication sequence and heat treatments are to be included.
- Details of the securing and collision arrangements, *see also* Part 9.
- Schematic oil fuel system, including controls and safety devices.
- Lubricating oil system.
- Starting air system.
- Cooling water system.
- Control engineering aspects in accordance with Part 16.
- Shielding of high pressure fuel pipes.
- Crankshaft design data as outlined in Section 4.
- Combustion pressure-displacement relationship.
- High pressure parts for fuel oil injection system with specification of pressures, pipe dimensions and materials.
- For new engine types that have not been approved by LR, the proposed type test programme.
- The type test report on completion of type testing for a new engine type. For mass produced engines a separate report is to be submitted for each engine requiring approval, *see* 10.5.

- Additionally, for mass produced engines:

(a) For consideration of an engine type to be approved:
  (i) Engine specification, *see* 11.1.4.
  (ii) Manufacturing processes and quality control information, *see* 11.2.3.
  (iii) List of sub-contractors for main parts.
  (iv) Procedures for configuring during commissioning.

(b) For engines of an approved type to be installed on a craft, a compliance and inspection certificate, *see* 11.4.

- For engine control, alarm monitoring and safety systems, the plans and information required by Pt 16, Ch 1,1.2.
- For electronically controlled engines, the plans and information required by 13.2.
- Schematic layouts showing details and arrangements of oil mist detection/monitoring and alarm systems.

2.1.2 The following information and calculations are to be submitted for information:

- Power/speed operational envelope.
- Calculations and information for short term high power operation where applicable.
- Longitudinal and transverse cross-section.
- Cast bedplate, thrust bearing bedplate, crankcase and frames.
- Cylinder head assembly.
- Cylinder liner.
- Piston assembly.
- Tie rod.
- Connecting rod, piston rod, and crosshead assemblies.
- Camshaft drive and camshaft general arrangement.
- Shielding and insulation of exhaust pipes.
- Operation and maintenance manuals.
- Vibration dampers/detuners and moment compensators.
- Details of turbochargers.
- Cross-sectional plans of the assembled turbo-charger with main dimensions.
- Fully dimensioned plans of the rotor.
- Material particulars with details of welding and surface treatments.
- Turbo-charger operating and test data.
- Manufacturer's burst test assessment.
- Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.
- Arrangement of interior lighting, where provided.
- Engine Type test programme, where required including proposals for short term high power operation.
- Alternative proposals for hydraulic tests where design features are such that modifications to the test requirements are necessary.
- Thrust bearing assembly (if integral with engine and not integrated in the bedplate).
- Counterweights, where attached to crank-throw, including fastening.
- Main engine holding down arrangement (metal chocks).

2.1.3 Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings, details of the chemical composition, heat treatment and mechanical properties are to be submitted.

2.1.4 A Failure Mode and Effects Analysis (FMEA) as required by Part 9 is to be submitted. The FMEA is to include the following associated sub-systems:

- Starting and stopping.
- Oil fuel.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

2.1.5 Plans and details for dead craft condition starting arrangements are to be submitted for appraisal, *see* 7.1.

2.1.6 For engine types built under licence it is intended that the above documentation be submitted by the Licensor. Each Licensee is then to submit the following:

- A list, based on the above, of all documents required with the relevant drawing numbers and revision status from both Licensor and Licensee.
- The associated documents where the Licensee proposes design modifications to components. In such cases a statement is to be made confirming the Licensor's acceptance of the proposed changes.

In all cases a complete set of endorsed documents will be required by the Surveyor attending the Licensee's works.

2.1.7 Where considered necessary additional documentation may be required.

■ *Section 3* **Materials**

3.1 Materials test and inspections

3.1.1 Components for engines are to be tested as indicated in Table 1.3.1 and in accordance with the relevant requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.2 Crankshaft materials

3.2.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings –
400 to 550 N/mm^2.

(b) Carbon-manganese steel forgings (normalised and tempered) –
400 to 600 N/mm^2.

(c) Carbon-manganese steel forgings (quenched and tempered) –
not exceeding 700 N/mm^2.

(d) Alloy steel castings –
not exceeding 700 N/mm^2.

Table 1.3.1 Material testing requirements

Component	Material tests	Non-destructive tests: Magnetic particle or Liquid penetrant	Non-destructive tests: Ultrasonic
Crankshaft	all	all	all
Crankshaft coupling flange (non-integral) for main propulsion engines	above 400 mm bore	—	—
Crankshaft coupling bolts	above 400 mm bore	—	—
Steel piston crowns	above 400 mm bore	above 400 mm bore	all
Piston rods	above 400 mm bore	above 400 mm bore	above 400 mm bore
Connecting rods, including bearing caps	all	all	above 400 mm bore
Crosshead	above 400 mm bore	—	—
Cylinder liner	above 300 mm bore	—	—
Cylinder cover	above 300 mm bore	above 400 mm bore	all
Steel castings for welded bedplates	all	all	all
Steel forgings for welded bedplates	all	—	—
Plates for welded bedplates, frames and entablatures	all	—	—
Crankcases, welded or cast	all	—	—
Tie rods	all	above 400 mm bore	—
Turbo-charger, shaft and rotor	above 300 mm bore	—	—
Bolts and studs for cylinder covers, crossheads, main bearings, connecting rod bearings	above 300 mm bore	above 400 mm bore	—
Steel gear wheels for camshaft drives	above 400 mm bore	above 400 mm bore	—

NOTES
1. For closed-die forged crankshafts the ultrasonic examination may be confined to the initial production and to subsequent occasional checks.
2. Magnetic particle or liquid penetrant testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.
3. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.
4. Bore dimensions refer to engine cylinder bores.
5. All required material tests are to be witnessed by the Surveyor unless alternative arrangements have been specifically agreed by LR.
6. For mass produced engines, *see* Section 10.

(e) Alloy steel forgings –
not exceeding 1000 N/mm^2.
(f) Spheroidal or nodular graphite iron castings –
370 to 800 N/mm^2.

■ *Section 4*
Crankshaft design

4.1 Application

4.1.1 The formulae given in this Section are applicable to solid or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

4.1.2 Alternative methods, including a fully documented stress analysis, will be considered.

4.1.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short term high power operation where applicable.

4.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

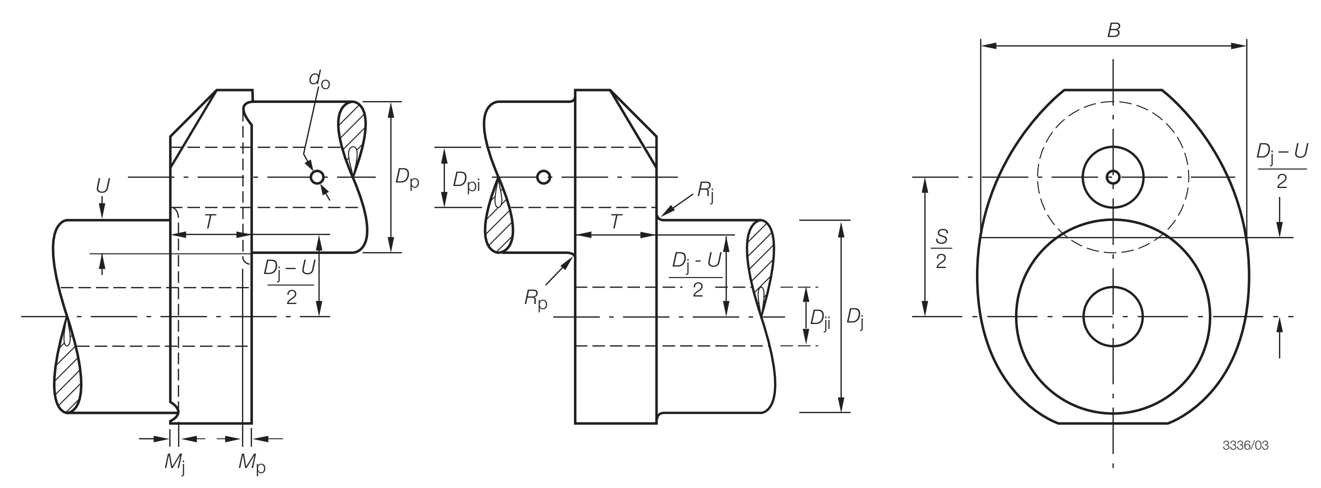
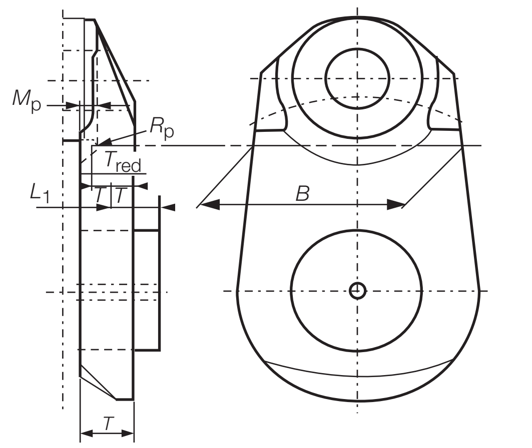


Fig. 1.4.1(a) Crank dimensions necessary for the calculation of stress concentration factors

4.2 Symbols

4.2.1 For the purposes of this Chapter the following symbols apply, *see also* Fig. 1.4.1:

h = radial thickness of web, in mm
k_e = bending stress factor
B = transverse breadth of web, in mm
D_p, D_j = outside diameter of pin or main journal, in mm
D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm
D_s = shrink diameter of main journal in web, in mm
d_o = diameter of radial oil bore in crankpin, in mm
F = alternating force at the web centreline, in N
K_1 = fatigue enhancement factor due to manufacturing process
K_2 = fatigue enhancement factor due to surface treatment
M_b = alternating bending moment at web centreline, in N-mm (NOTE: alternating is taken to be 1/2 range value)
M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore
M_p, M_j = undercut of fillet radius into web measured from web face, in mm
R_p, R_j = fillet radius at junction of web and pin or journal, in mm
S = stroke, in mm
T = axial thickness of web, in mm
T_a = alternating torsional moment at crankpin or crank journal, in N-mm (NOTE: alternating is taken to be 1/2 range value)
U = pin overlap
α_B = bending stress concentration factor for crankpin
α_T = torsional stress concentration factor for crankpin
β_B = bending stress concentration factor for main journal
β_Q = direct shear stress concentration factor for main journal
β_T = torsional stress concentration factor for main journal
γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin
γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin
σ_{ax} = alternating axial stress, in N/mm^2
σ_b = alternating bending stress, in N/mm^2
σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2
σ_p,σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2



Crankshaft without overlap

Fig 1.4.1(b)
Crank dimensions for crankshaft without overlap

σ_u = specified minimum UTS of material, in N/mm^2
σ_y = specified minimum yield stress of material, in N/mm^2
σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2
σ_Q = alternating direct stress, in N/mm^2
τ_a = alternating torsional stress, in N/mm^2
τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2
τ_{tob} = maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

4.3 Stress concentration factors

4.3.1 Geometric factors. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in Table 1.4.1.

Table 1.4.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jb}
$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$		0,50

NOTES
1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.
2. A lower limit of *u* can be extended down to large negative values provided that:
   (i) If calculated *f*(rec) < 1 then the factor *f*(rec) is not to be considered (*f*(rec) = 1)
   (ii) If *u* < –0,5 then f(ut) and f(ru) are to be evaluated replacing the actual value of *u* by –0,5.
3. For crankshafts without overlap *see also* 4.3.6.

4.3.2 Crankpin stress concentration factors:

Bending

α_B = 2,70 $f(ut)\, f(t)\, f(b)\, f(r)\, f(dp)\, f(dj)\, f(rec)$

where

$f(ut)$ = $1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

$f(t)$ = $2{,}18t^{0{,}717}$

$f(b)$ = $0{,}684 - 0{,}0077b + 0{,}147b^2$

$f(r)$ = $0{,}208r_p^{(-0{,}523)}$

$f(dp)$ = $1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

$f(dj)$ = $1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

f(rec) = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between *u* = – 0,5 and 0,5

Torsion

α_T = 0,8 $f(ru)\, f(b)\, f(t)$

where

$f(ru)$ = $r_p^{-(0{,}22 + 0{,}1u)}$

$f(b)$ = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t)$ = $t^{(-0{,}145)}$

4.3.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts)

Bending

β_B = $2{,}71 f_B(ut)\, f_B(t)\, f_B(b)\, f_B(r)\, f_B(dj)\, f_B(dp)\, f(rec)$

where

$f_B(ut)$ = $1{,}2 - 0{,}5t + 0{,}32t^2 - u\,(0{,}80 - 1{,}15t + 0{,}55t^2) - u^2\,(2{,}16 - 2{,}33t + 1{,}26t^2)$

$f_B(t)$ = $2{,}24t^{0{,}755}$

$f_B(b)$ = $0{,}562 + 0{,}12b + 0{,}118b^2$

$f_B(r)$ = $0{,}191r_{jB}^{(-0{,}557)}$

$f_B(dj)$ = $1 - 0{,}644d_j + 1{,}23(d_j)^2$

$f_B(dp)$ = $1 - 0{,}19d_p + 0{,}0073(d_p)^2$

$f(rec)$ = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between *u* = – 0,5 and 0,5

Direct shear

β_Q = $3{,}01 f_Q(u)\, f_Q(t)\, f_Q(b)\, f_Q(r)\, f_Q(dp)\, f(rec)$

where

$f_Q(u)$ = $1{,}08 + 0{,}88u - 1{,}52(u)^2$

$$f_Q(t) = \frac{t}{0{,}0637 + 0{,}937t}$$

$f_Q(b)$ = $b - 0{,}5$

$f_Q(r)$ = $0{,}533r_{jB}^{(-0{,}204)}$

$f_Q(dp)$ = $1 - 1{,}19d_p + 1{,}74(d_p)^2$

$f(rec)$ = $1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$
valid only between *u* = – 0,5 and 0,5

Torsion

β_T = $0{,}8 f(ru)\, f(b)\, f(t)$

where

$f(ru)$ = $r_{jT}^{-(0{,}22 + 0{,}1u)}$

$f(b)$ = $7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t)$ = $t^{(-0{,}145)}$

4.3.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

γ_B = $3 - 5{,}88 \bullet d_o + 34{,}6 \bullet d_o^2$

- Torsion

γ_T = $4 - 6 \bullet d_o + 30 \bullet d_o^2$

4.3.5 Where experimental measurements of the stress concentrations are available these may be used. The full documented analysis of the experimental measurements is to be submitted for consideration.

4.3.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as:

T_{red} = $T - (M_p - R_p)$ and the web width *B* is to be taken in way of the crankpin fillet radius centre *see* Fig. 1.4.1(b).

4.4 Nominal stresses

4.4.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

4.4.2 Nominal bending stresses are referred to the web bending modulus.

4.4.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \text{ N/mm}^2$$

where

$$Z_{web} = \frac{BT^2}{6} \text{ mm}^3$$

k_e = 0,8 for crosshead engines
= 1,0 for trunk piston engines.

4.4.4 Nominal alternating bending stress in the outlet of the crankpin oil bore:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

where

M_{BON} is taken as the ½ range value
$M_{BON} = \pm$ ½ $(M_{BOmax} - M_{BOmin})$

and

$M_{BO} = (M_{BTO} \cos\psi + M_{BRO} \sin\psi)$, *see* Fig. 1.4.2

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$$Z_{crankpin} = \frac{\pi}{32} \frac{D^4 - d^4}{D}$$

$Z_{crankpin}$ related to the cross-section of axially bored crankpin.

4.4.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_b in 4.4.3.

4.4.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

4.4.7 Nominal alternating direct shear stress:

$$\sigma_Q = \pm \frac{F}{A_{web}} k_e \text{ N/mm}^2$$

where

$A_{web} = BT$ mm²

4.4.8 The nominal alternating torsional stress, τ_a, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

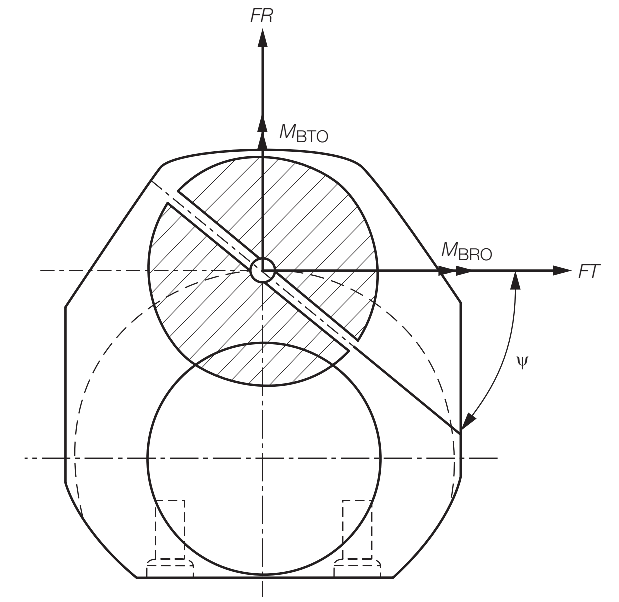


Fig. 1.4.2 Crankpin section through the oil bore

4.4.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with Part 13 are to be submitted.

4.4.10 Nominal alternating torsional stress:

$$\tau_a = \pm \frac{T_a}{Z_T} \text{ N/mm}^2$$

where

Z_T = torsional modulus of crankpin and main journal

$$= \frac{\pi}{16}\left[\frac{(D^4 - d^4)}{D}\right] \text{ mm}^3$$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring [*] in one of the cylinders). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

If T_a is not known, a value can be calculated by the following formula as an approximation in the first instance:

$$T_a = \left((18{,}6 - 0{,}0132 D_e) \times \left(\frac{\sigma_u + 160}{560}\right)\right) \times Z_e \text{ N/mm}$$

where

$$D_e = D_j \sqrt[3]{1 + \left(\frac{D_{ji}}{D_j}\right)^4}$$

or

$$D_p \sqrt[3]{1 - \left(\frac{D_{pi}}{D_p}\right)^4}$$

whichever is the smaller

Z_e = corresponding torsional modulus

$$= \pi \frac{(D_e{}^4 - d^4)}{16D_e} \text{ mm}^3.$$

4.4.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in 4.4.10, occurring at the most torsionally loaded mass point of the crankshaft system.

4.4.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating tersional stress is not exceeded.

4.4.13 Reference should be made to Pt 13, Ch 1 on the calculations of torsional vibration characteristics.

4.4.14 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk piston engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

4.5 Maximum stress levels

4.5.1 Crankpin fillet:

- Maximum alternating bending stress:

$$\sigma_p = \alpha_B (\sigma_b + \sigma_{ax}) \text{ N/mm}^2$$

where

α_B = bending stress concentration, *see* 4.3.2.

- Maximum alternating torsional stress:

$$\tau_p = \alpha_T \tau_{ax} \text{ N/mm}^2$$

where

α_T = torsional stress concentration, *see* 4.3.2

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.5.2 Outlet of crankpin oil bore

- Maximum alternating bending stress:

$$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax}) \text{ N/mm}^2$$

where

γ_B = bending stress concentration factor, *see* 4.3.4

- Maximum alternating torsional stress:

$$\tau_{tob} = \gamma_T \tau_a \text{ N/mm}^2$$

where

γ_T = torsional stress concentration factor, *see* 4.3.4

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.5.3 Crank journal fillet (not applicable to semi-built crankshafts):

Maximum alternating bending stress:

$$\sigma_j = \beta_B (\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q \text{ N/mm}^2$$

where

β_B = bending stress concentration, *see* 4.3.3

β_Q = direct stress concentration, *see* 4.3.3.

Maximum alternating torsional stress:

$$\tau_j = \beta_T \tau_a \text{ N/mm}^2$$

where

β_T = torsional stress concentration, *see* 4.3.3

τ_a = nominal alternating torsional stress in main journal N/mm^2.

4.6 Equivalent alternating stress

4.6.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{ep}, \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \text{ N/mm}^2$$

where

σ = σ_p or σ_j N/mm^2

τ = τ_p or τ_j N/mm^2

4.6.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3} \sigma_{bo} \left[1 + 2 \sqrt{1 + \frac{9}{4} \left(\frac{\tau_{to}}{\sigma_{bo}}\right)^2} \right] \text{ N/mm}^2.$$

4.7 Fatigue strength

4.7.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_p^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u} \sqrt{\frac{1}{R_p}}\right) \text{ N/mm}^2$$

To calculate the fatigue strength in the oil bore area, replace R_p with ½d_o and σ_{fp} with σ_{fob}.

$$\sigma_{fj} = K_1 K_2 (0{,}42\sigma_u + 39{,}3) \left(0{,}264 + 1{,}073 D_j^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u} \sqrt{\frac{1}{R_j}}\right) \text{ N/mm}^2$$

where

σ_u = UTS of crankpin or crank journal as appropriate, in N/mm^2

K_1 = fatigue endurance factor appropriate to the manufacturing process
= 1,05 for continuous grain-flow (CGF) or die-forged
= 1,0 for freedom forged (without CGF)
= 0,93 for cast steel manufactured using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

4.7.2 A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened
= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

4.8 Acceptability criteria

4.8.1 The acceptability factor, Q, is to be greater than 1,15:

$$Q = \frac{\sigma_f}{\sigma_e}$$ for crankpin, journal and the outlet of crankpin oil bore

where

σ_f = σ_{fp}, σ_{fj} or $\sigma_{f\,ob}$

σ_e = σ_{ep}, σ_{ej} or σ_{eob}.

4.9 Crankshaft oil hole

4.9.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

4.9.2 Fatigue strength calculations or, alternatively, fatigue test results may be required to demonstrate acceptability.

4.9.3 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

4.10 Shrink fit of semi-built crankshafts

4.10.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s \sqrt{1 - \frac{4000 FoS\, M_{max}}{\mu\, \pi\, D_s^2\, L_s\, \sigma_{yj}}}$$

where the symbols are as defined in 4.10.7.

4.10.2 When 4.10.1 cannot be complied with, then 4.10.7 is not applicable. In such cases δ_{min} and δ_{max} are to be established from FEM calculations.

4.10.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

4.10.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than $0{,}015D_j$ or $0{,}5(D_s - D_j)$.

4.10.5 The distance, y, between the underside of the pin and the shrink diameter should be greater than $0{,}05D_s$.

4.10.6 Deviations from these parameters will be specially considered.

4.10.7 The proposed diametral interference is to be within the following limits, *see also* Fig. 1.4.3:
The minimum required diametral interference is to be taken as the greater of:

$$\delta_{min} = \frac{12{,}156 \times 10^6\,(FoS)}{T\, Ds\, \mu\, E} \; \frac{P}{R} \left(1 + C\right) \frac{k^2 - l^2}{(k^2 - 1)(1 - l^2)} \text{ mm}$$

or

$$\delta_{min} = \frac{\sigma_y\, D_s}{E} \text{ mm}$$

where

h = minimum radial thickness of the web around the diameter D_s, mm

$k = \dfrac{D_o}{D_s}$

$l = \dfrac{D_{ji}}{D_s}$

C = ratio of torsional vibratory torque to the mean transmitted torque at the P/R rating being considered

D_o = $D_s + 2h$, mm

D_s = shrink diameter, mm

E = Young's modulus of elasticity of crankshaft material, N/mm^2

FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability

P = output power, in kW

R = speed at associated power, in rpm

T = crankweb thickness, in mm

μ = coefficient of static friction to be taken as 0,2 for degreased surfaces. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability

σ_{yj} = minimum yield strength of material for journal pin

M_{max} = absolute maximum value of the torque taking Ch 8,2 into consideration

L_s = length of shrink fit, in mm

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y\, D_s}{E} + \frac{0{,}8D_s}{1000} \text{ mm}$$

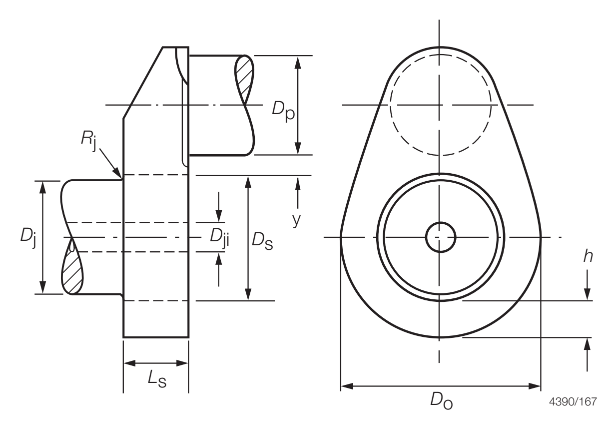


Fig. 1.4.3 Crankthrow of semi-built crankshaft

4.10.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

■ *Section 5* Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion, taking into account the installation of explosion relief valves required by Section 6, and the doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 All welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.3.2 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of the Rules for Materials, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

■ *Section 6* Safety arrangements on engines

6.1 Cylinder relief valves

6.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves.

6.2 Crankcase relief valves

6.2.1 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

6.2.2 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

6.2.3 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with Section 15. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be type tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.2.4 In engines having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, relief valves may be omitted.

6.2.5 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.6 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc., crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc., respectively.

6.2.7 In engines having cylinders exceeding 300 mm bore at least one valve is to be fitted in way of each main crank throw.

6.2.8 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.2.9 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.2.10 The free area of each relief valve is to be not less than 45 cm^2.

6.2.11 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.2.12 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase. No deduction shall be made for the volumes of the rotating and reciprocating components.

6.2.13 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

- Description of valve with details of function and design limits.
- Copy of type test certification.
- Installation instructions.
- Maintenance and in-service instructions to include testing and renewal of any sealing arrangements.
- Actions required after a crankcase explosion.

6.2.14 A copy of the installation and maintenance manual required by 6.2.13 is to be provided on board the ship.

6.2.15 Plans showing details and arrangements of the relief valves are to be submitted for approval, *see* 2.1.

6.2.16 The valves are to be provided with suitable markings that include the following information:

- Name and address of manufacturer.
- Designation and size.
- Month/Year of manufacture.
- Approved installation orientation.

6.3 Vent pipes

6.3.1 Through ventilation, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for trunk piston type dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion. Vent or breather pipes from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.3.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.3.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.4 Warning notice

6.4.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.5 Crankcase access and lighting

6.5.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

6.5.2 Interior lighting, where fitted, is to be flameproof.

6.6 Oil mist detection

6.6.1 Where crankcase oil mist detection arrangements are fitted, they are to be of a type approved by LR, tested in accordance with Section 16 and comply with 6.6.2 to 6.6.15.

6.6.2 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist detection equipment manufacturer's instructions/ recommendations. The following particulars are to be included in the instructions:

(a) A schematic layout of the engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to the detector.
(b) Evidence of study to justify the selected locations of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry, and the predicted crankcase atmosphere where oil mist can accumulate.
(c) The manufacturer's maintenance and test manual.
(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

6.6.3 A copy of the oil mist detection equipment maintenance and test manual required by 6.6.2 is to be provided on board the craft.

6.6.4 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

6.6.5 In the case of multi engine installations, each engine is to be provided with individual, dedicated oil mist detection arrangements and alarm(s).

6.6.6 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

6.6.7 Alarms and safeguards for the oil mist detection system are to be in accordance with Pt 16, Ch 1 as applicable.

6.6.8 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements.

6.6.9 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

6.6.10 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with Pt 16, Ch 1, as applicable.

6.6.11 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See* 2.1.

6.6.12 The equipment together with detectors is to be tested when installed on the test bed and on board the craft to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

6.6.13 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

6.6.14 Where alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars – type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g., bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

6.6.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

■ *Section 7* Starting arrangements

7.1 Dead craft condition starting arrangements

7.1.1 Means are to be provided to ensure that machinery can be brought into operation from the dead craft condition without external aid.

7.1.2 Dead craft condition for the purpose of 7.1.1 is to be understood to mean a condition under which the main propulsion plant and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries is assumed to be available for starting and operating the propulsion plant.

7.1.3 Where the emergency source of power is an emergency generator which fully complies with the requirements of Pt 16, Ch 2, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

7.1.4 Where there is no emergency generator installed or an emergency generator does not comply with Pt 16, Ch 2, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board the craft without external aid. If, for this purpose, an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead craft condition.

7.2 Starting arrangements – Air compressors

7.2.1 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by 7.3. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of 7.1 is to be ignored.

7.2.2 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

7.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

7.2.4 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

7.3 Air receivers

7.3.1 Where the main engine is arranged for air starting the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Pt 15, Ch 4.

7.3.2 For multi-engine installations, where more than one engine is driving each propulsion shaft line, the following requirements apply:

(a) Twin engine installations driving fixed pitch propeller, where one of the engines can be reversed, six consecutive starts per engine are required.
(b) For all other types of multi-engine installations three consecutive starts per engine are required.

7.3.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

7.3.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C, *see also* Pt 15, Ch 4,9.2.

7.3.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

7.4 Starting air pipe systems and safety fittings

7.4.1 Air start piping systems are in general to comply with the requirements of Part 15, due regard being paid to the particular type of installation.

7.4.2 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

7.4.3 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

7.4.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

7.4.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

7.4.6 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

7.4.7 In direct reversing engines bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

7.4.8 Alternative safety arrangements may be submitted for consideration.

7.5 Electrical starting arrangements

7.5.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by 7.3.

7.5.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

7.5.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

7.5.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in 7.5.1 and 7.5.3.

7.5.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery level.

7.5.6 The requirements for battery installations are given in Pt 16, Ch 2.

7.6 Starting of the emergency source of power

7.6.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 10ºC. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

7.6.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

7.6.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.
(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.
(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

7.6.4 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

7.6.5 When hand (manual) starting is not practicable, the provisions of 7.6.2 and 7.6.3 are to be complied with except that starting may be manually initiated.

7.6.6 Electric starting arrangements are to also satisfy 7.5.2 to 7.5.5.

7.7 Engine control, alarm monitoring and safety system power supplies

7.7.1 Power supplies are to be arranged so that power for electrically powered control, alarm monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each source of stored energy.

7.7.2 Where adequate battery and charging capacity exists, an engine starting battery may be used as one source of electrical power required by 8.6.1.

7.7.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

■ *Section 8*
Piping systems

8.1 General

8.1.1 Diesel engine piping systems are, in general, to comply with the requirements of Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

8.1.2 Short lengths of synthetic rubber hoses that comply with the requirements of Pt 15, Ch 1,13 may be used in diesel engine piping systems to accommodate relative movement between machinery and fixed piping systems.

8.2 Oil fuel systems

8.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3,3 and 3,4, as applicable.

8.2.2 All external high pressure fuel delivery lines between the high pressure fuel pumps and fuel injectors are to be protected with a jacketed piping system capable of containing fuel from a high pressure line failure. If flexible hoses are used for shielding purposes, these arrangements are to be approved.

8.2.3 The protection is to prevent oil fuel or oil fuel mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any oil fuel leakage and for preventing contamination of the lubricating oil by oil fuel.

8.3 Oil fuel filters and fittings

8.3.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

8.3.2 Drip trays are to be fitted under oil fuel filters and other fittings which are required to be opened up frequently for cleaning or adjustment or where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

8.4 Lubricating oil systems

8.4.1 Lubricating oil arrangements are to comply with the requirements of Part 15 as applicable.

8.5 Engine cooling water systems

8.5.1 Cooling water arrangements are to comply with the requirements of Part 15, as applicable.

8.6 Inlet and exhaust systems

8.6.1 Engine inlets are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

8.6.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.6.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

8.6.4 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.6.5 Plastic pipes intended for exhaust systems are to be in accordance with a recognised Code or Standard suitable for the intended service conditions.

8.7 High pressure oil systems

8.7.1 Where flammable oils are used in high pressure systems, the oil pipe lines between the high pressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high pressure line failure.

■ *Section 9* Control and monitoring

9.1 General

9.1.1 The Control and Monitoring systems are to comply with the requirements of Part 16.

9.1.2 While it is recommended that oil mist detection, engine bearing temperature monitors or alternative methods for crankcase protection be fitted, they are in any case to be provided:

(a) When arrangements are fitted to override the automatic stop for excessive reduction of the lubricating oil supply pressure.

(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

Notes:

1. For medium and high speed engines automatic shutdown of the engine is to occur, *see also* 9.7.2.
2. Where arrangements are made to override the automatic shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.
3. Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build-up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see* 6.6.14.

9.1.3 All main and auxiliary engines intended for essential services are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 220 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Main engine governors

9.2.1 An efficient governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be classed by more than 15 per cent.

9.3 Auxiliary engine governors

9.3.1 Auxiliary engines intended for driving electric generators are to be fitted with governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation under the following conditions:

(a) Full load is suddenly taken off.
(b) Full load is suddenly applied following a minimum of 15 minutes no load. If the BMEP is greater than 8 bar the load may be applied as follows:

$$\frac{800}{BMEP}\ \%\ \left(\text{but not less than } \frac{1}{3} \text{ full load}\right), \text{ then full load}$$

being attained in not more than two equal stages as rapidly as possible.

9.3.2 Emergency engines are to comply with 9.3.1 except that the initial load required by 9.3.1(b) is to be not less than the total connected emergency statutory load.

9.3.3 For alternating current installations, the permanent speed variation of the machines intended for parallel operation are to be equal within a tolerance of ±0,5 per cent. Momentary speed variations with load changes in accordance with 9.5.1 are to return to and remain within one per cent of the final steady state speed in not more than eight seconds.

9.4 Overspeed protective devices

9.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable (reversible) pitch propeller, also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

9.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by 9.4 or 9.5 and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

9.5 Engine stopping

9.5.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

9.6 Unattended machinery

9.6.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by 9.1 to 9.8 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

9.6.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by Tables 1.9.1 and 1.9.2, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.6.3 Means are to be provided to prevent leaks from high pressure oil fuel injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

9.6.4 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.7 Diesel engines for propulsion purposes

9.7.1 Alarms and safeguards are indicated in 9.7.2 to 9.7.8 and Table 1.9.1, *see also* 9.1.2 and 9.6.3.

9.7.2 Alarms are to operate, and indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be reduced for the following fault conditions:

(a) Oil mist in crankcase or high bearing temperature (if detection is fitted, *see* 9.1.2).
(b) Low piston coolant pressure or flow.
(c) High piston coolant outlet temperature.
(d) Low cylinder coolant pressure or flow.
(e) High cylinder coolant temperature.
(f) High exhaust gas temperature per cylinder or deviation from average temperature (high).
(g) High thrust bearing temperature.
(h) Low cylinder lubricator flow.

NOTES:

1. For medium and high speed engines automatic slowdown is required for items (d), (e), (f) and (h). However, an automatic shutdown is required for (a).
2. Common sensors are acceptable for alarms and slowdown functions.

9.7.3 Reduction of speed or power may be effected by either manual or automatic control.

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.

9.7.5 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*see continuation*)

Item	Alarm	Note
Lubricating oil sump level	Low	Engines (and gearing if fitted)
Lubricating oil inlet pressure*++	1st stage Low++	Engines (and gearing if fitted)
	2nd stage Low	Automatic shutdown engines (and gearing if fitted), *see* 9.6.2
Lubricating oil inlet temperature*	High	Engines (and gearing if fitted)
Lubricating oil filters differential pressure	High	—
Cylinder lubricator flow	Low unit	One sensor per lubricator
Piston coolant inlet pressure	Low	If a separate system
Piston coolant outlet temperature*	High	Per cylinder (if a separate system)
Piston coolant outlet flow*	Low	Per cylinder (if a separate system)
Cylinder coolant inlet pressure or flow*++	Low	—
Cylinder coolant outlet temperature*++	1st stage High++	Per cylinder (if a separate system) or manifold++
	2nd stage High	Automatic shutdown medium and high speed engines, *see* 9.6.2
Sea-water cooling pressure	Low	—
Thrust bearing temperature*	High	—
Common rail servo oil pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Oil fuel pressure from booster pump	Low	—
Oil fuel temperature or viscosity*	High and Low	Heavy oil only
Common rail fuel oil pressure	Low	—
Charge air cooler outlet temperature	High and Low	4 stroke medium and high speed engines
Scavenge air temperature	High	Per cylinder, (fire detection, 2 stroke engines)
Exhaust gas temperature*	High	Per cylinder (or deviation from average temperature)

Table 1.9.1 Oil engines for propulsion purposes alarms and safeguards (*conclusion*)

Item	Alarm	Note
Turbo-charger exhaust gas outlet temperature*	High	—
Turbo-charger lubricating oil inlet pressure	Low	If system not integral with turbo-charger
Turbo-charger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbo-charger. *See* Note 4
Starting air pressure*	Low	Before engine manoeuvring valve
Overspeed*	High	Automatic shutdown of engine, *see also* 9.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Automatic start of engine	Failure	*See* 9.7.6
Electrical starting battery charge level	Low	—

NOTES
1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for medium and high speed engines.
2. For engines and gearing of 1500 kW or less, only the items marked* are required.
3. For service craft with engines of 500 kW or less, only the items marked ++ are required.
4. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer's instructions may be submitted for consideration.

9.7.6 The number of automatic consecutive attempts which fail to produce a start is to be limited to three attempts. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see* 7.5.

9.7.7 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

9.8 Auxiliary and other engines

9.8.1 Alarms and safeguards are indicated in Table 1.9.2, *see also* 9.1.2 and 9.6.3.

9.8.2 For engines operating on heavy oil fuel, automatic temperature of viscosity controls is to be provided.

Table 1.9.2 Auxiliary engine alarms and safeguards

Item		Alarm	Note
Lubricating oil inlet temperature		High	—
Lubricating oil inlet pressure	1st stage	Low	—
	2nd stage	Low	Automatic shutdown of engine, *see* 9.6.2
Coolant outlet temperature	1st stage	High	For engines over 220 kW
	2nd stage	High	For engines over 220 kW Automatic shutdown of engine, *see* 9.6.2
Coolant pressure or flow		Low	—
Overspeed		High	Automatic shutdown of engine, *see also* 9.4. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration
Starting air pressure		Low	—
Electrical starting battery charge level		Low	—
Oil fuel inlet temperature or viscosity		High and low	Heavy oil only
Common rail servo oil pressure		Low	—
Common rail fuel oil pressure		Low	—

9.9 Alarms and safeguards for emergency diesel engines

9.9.1 These requirements apply to emergency diesel engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.

9.9.2 Alarms and safeguards are indicated in Table 1.9.3. *See also* 9.1.2 and 9.6.3.

9.9.3 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the craft.

9.9.4 Regardless of the engine output, if shutdowns additional to those specified in Table 1.9.3 are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

Table 1.9.3 Alarms and safeguards for emergency diesel engines

Item	Alarm	Alarm	Note
Emergency diesel engine	≥ 220 kW	<220 kW	
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See* 9.6.3
Lubricating oil temperature	High	—	—
Lubricating oil pressure	Low	Low	—
Oil mist concentration in crankcase	High	—	*See* Note
Coolant pressure or flow	Low	—	—
Coolant temperature (can be air)	High	High	—
Overspeed	High	—	Automatic shutdown
NOTE For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.			

9.9.5 Grouped alarms of at least those items listed in Table 1.9.3 are to be arranged on the bridge.

9.9.6 In addition to the fuel oil control from outside the space, a local means of engine shutdown is to be provided.

9.9.7 Local indications of at least those items listed in Table 1.9.3 are to be provided within the same space as the diesel engines and are to remain operational in the event of failure of the alarm and safety systems.

■ *Section 10* Requirements for craft which are not required to comply with the HSC Code

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply to craft which are not required to comply with the HSC code, unless specifically exempted by the contents of this Section.

10.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

10.1.3 The requirements of 1.5.1 do not apply to service craft less than 24 m.

10.2 Details to be submitted

10.2.1 The requirements of 2.1.1 do not apply to yachts or service craft less than 24 m, *see* Pt 9, Ch 1,6.1.

10.2.2 The requirements of 2.1.4 (FMEA as detailed in Part 9) do not apply to yachts or to service craft less than 24 m unless used for passenger carrying duties.

10.3 Materials

10.3.1 Materials for which no provision is made in this Part of the Rules may be accepted provided that they comply with an approved specification and such tests as may be considered necessary.

10.4 Crankshaft design

10.4.1 The requirements of Section 4 do not apply to the following types of craft having main or auxiliary diesel engines with a power output not exceeding 110 kW:
(a) service craft of less than 24 m,
(b) yachts,
(c) ACVs.

Section 11
Mass produced engines

11.1 Definition

11.1.1 Mass produced engines, for main and auxiliary purposes, are defined as those which are produced under the following criteria:
(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled engines according to a specified programme.
(e) With appraisal by final examination of engines selected at random after workshop testing.

11.1.2 Castings, forgings and other parts for use in mass produced engines are also to be produced by methods similar to those given in 11.1.1(a), (b) and (c), with appropriate inspection.

11.1.3 Pressure testing of components is to comply with Pt 9, Ch 2,2.2.

11.1.4 The specification of a mass produced engine is to define the limits of manufacture of all component parts. The total production output is to be certified by the manufacturer and verified as may be required, by LR in accordance with the agreed manufacturer's quality assurance scheme, *see* 11.1.1(a).

11.2 Procedure for approval of mass produced engines

11.2.1 The procedure outlined in 11.2.2 to 11.2.5 applies to the inspection and certification of mass produced oil engines having a bore not exceeding 300 mm.

11.2.2 For the approval of a mass produced engine type, the manufacturer is to submit:
(a) The plans and particulars required by 2.1 for assessment;
(b) As necessary, information to assess compliance with Section 4;
(c) A list of subcontractors for main parts; and
(d) Control, alarm monitoring and safety system configuration procedures, *see* 11.4.2.

11.2.3 The manufacturer is to supply full information regarding the manufacturing processes and quality control procedures applied in the workshops. The information is to address the following:
(a) Organisation of quality control systems.
(b) Recording of quality control operations.
(c) Qualification and independence of personnel in charge of quality control.

11.2.4 A running type test of at least 100 hours duration is to be carried out on an engine chosen from the production line. The type testing is to comply with 11.5.

11.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced engine. LR is to be informed, without delay, of any change in the design of the engine, including changes to the software and control, alarm monitoring or safety systems, in the manufacturing or quality, control processes, in the selection of materials or in the list of subcontractors for main parts.

11.3 Continuous review of production

11.3.1 LR Surveyors are to be provided free access to the manufacturer's workshops and to the quality control files.

11.3.2 The control of production, which is subject to survey, is to include the following:
(a) Inspection and testing records are to be maintained to the satisfaction of the Surveyor.
(b) The system for identification of parts is to be in accordance with recognised practice, and acceptable to LR.

(c) The manufacturer is to provide full information about the quality control of the parts supplied by subcontractors for which certification may be required. LR reserves the right to apply direct and individual inspection procedures for parts supplied by subcontractors when deemed necessary.
(d) At the request of an attending LR surveyor, a workshop test may be required for an individual engine.

11.4 Compliance and inspection certificate

11.4.1 Each engine which is to be installed on a ship classed by LR is to be supplied with a statement certifying that the engine is identical to the one which underwent the tests specified in 11.2.4, and state the test and inspection results. The statement is to be made on a form agreed with LR. Each statement is to include the identification number which appears on the engine. A copy of this statement is to be submitted to LR.

11.4.2 The certificate is to include reference to the manufacturer's procedures to be followed during commissioning for configuring control, alarm monitoring and safety systems for multi-purpose engines or other engine types that require parameters and settings to be adjusted for the intended application.

11.5 Type test conditions

11.5.1 The requirements in this Section are applicable to the type testing of mass produced internal combustion engines where the manufacturer has requested approval. Omission or simplification of the type test requirements will be considered by LR for engines of an established type on application by the manufacturer.

11.5.2 The engine to be tested is to be selected from the production line and agreed by LR.

11.5.3 The type tests are to be conducted with the engine control systems operational in the approved configuration, *see* 2.1.5 and 2.1.6. Configuration management documents are to be reviewed at testing for validity and referenced in the type test report.

11.5.4 The duration and programme of type tests is to include the following:
(a) 80 h at rated output.
(b) 8 h at 110 per cent overload.
(c) 10 h at varying partial loads (25 per cent, 50 per cent, 75 per cent and 90 per cent of rated output).
(d) 2 h at maximum intermittent loads.
(e) Starting tests.
(f) Reverse running of direct reversing engines.
(g) Testing of speed governor.
(h) Testing of over-speed device.
(j) Testing of lubricating oil system failure alarm device.
(k) Testing of the engine with turbocharger out of action when applicable.
(l) Testing of minimum speed for main propulsion engines and the idling speed for auxiliary engines.

11.5.5 The type tests in 11.5.4 at the required outputs are to be combined together in working cycles for the whole duration within the limits indicated. *See also* 11.5.11 and 11.5.12.

11.5.6 The overload testing required by 11.5.4 is to be carried out with the following conditons:
(a) 110 per cent of rated power at 103 per cent revolutions per minute for engines directly driving propellers.
(b) 110 per cent of rated power at 100 per cent revolutions per minute for engines driving electrical generators or for other auxiliary purposes.

11.5.7 For prototype engines, the duration and programme of tests are to be specially agreed between the manufacturer and LR.

11.5.8 As far as practicable during type testing, the following particulars are to be continuously recorded:
(a) Ambient air temperature.
(b) Ambient air pressure.
(c) Atmospheric humidity.
(d) External cooling water temperature.
(e) Fuel and lubrication oil characteristics.

11.5.9 In addition to the particulars stated in 11.5.8 and as far as practicable, the following are also to be continuosly measured and recorded:
(a) Engine revolutions per minute.
(b) Brake power.
(c) Torque.
(d) Maximum combustion pressure.
(e) Indicator pressure diagrams where practicable.
(f) Exhaust smoke (with an approved smoke meter).
(g) Lubricating oil pressure and temperature.
(h) Exhaust gas temperature in exhaust manifold, and, where facilities are available, from each cylinder.
(j) For turbocharged engines:
- Turbocharger revolutions per minute.
- Air temperature and pressures before and after turbo-blower and charge cooler.
- Exhaust gas temperature and pressures before and after the turbine.
- The cooling water inlet temperature to the charge air cooler.

11.5.10 After the type test, the main parts and especially those subject to wear are to be dismantled for examination by LR Surveyors.

11.5.11 For engines that are required to be approved for different purposes (multi-purpose engines), and that have different performance profiles and control, alarm, monitoring and safety systems configurations for each purpose, the programme and duration of test is to be modified to cover the whole range of the engine performance, taking into account the most severe conditions and intended purpose(s).

11.5.12 The rated output for which the engine is to be tested is the output corresponding to that declared by the manufacturer and agreed by LR, i.e. actual maximum power which the engine is capable of delivering continuously between the normal maintenance intervals stated by the manufacturer at the rated speed and under the stated ambient conditions.

Section 12
Mass produced turbo-chargers

12.1 Application

12.1.1 The following procedure applies to the inspection of exhaust driven turbo chargers which are manufactured on the basis of mass production methods similar to 11.1 as applicable and for which the maker has requested the approval.

12.2 Procedure for approval of mass produced turbo-chargers

12.2.1 The procedure outlined in 12.2.2 to 12.2.5 applies to the inspection and certification of mass produced turbo-chargers when a simplified method of inspection has been requested by the manufacturers.

12.2.2 For the approval of a mass produced turbo-charger, the manufacturer is to submit, in addition to the plans and particulars required by Chapter 1, as applicable, a list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.

12.2.3 The manufacturer will supply full information regarding the material and quality control system used in the organisation as well as the inspection methods, the way of recording and proposed frequency, and the method of material testing of important parts.

12.2.4 A Type test, *see* Pt 9, Ch 2,3.1, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor. The performance data which may have to be verified are to be made available at the time of the type test. For manufacturers who have facilities for testing the turbo-charger unit on an engine for which the turbo-charger is intended, substitution of the hot running test by a test run of one hour's duration at overload (110 per cent of the rated output) may be considered.

12.2.5 LR reserves the right to limit the duration of validity of approval of a mass produced turbo-charger. LR is to be informed, without delay, of any change in the design of the turbo-charger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

12.3 Continuous inspection of individual units

12.3.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by 12.3.3 to 12.3.7 as deemed necessary, and to have free access to all control records and subcontractor's certificates.

12.3.2 Each individual unit is to be tested in accordance with 12.3.4 to 12.3.7 by the maker who is to issue a final certificate.

12.3.3 Rotating parts of the turbo-charger blower are to be marked for easy identification with the appropriate certificate.

12.3.4 Material tests of the rotating parts are to be carried out by the maker or his subcontractor in accordance with the requirements of the Rules for Materials as applicable. The relevant certificate is to be produced and filed to the satisfaction of the Surveyor.

12.3.5 Pressure tests are to be carried out in accordance with Table 2.2.1. Special consideration will be given where design or testing features may require modification of the test requirements.

12.3.6 Dynamic balancing and overspeed tests are to be carried out, *see* Pt 9, Ch 2,3.2 and 3.3, in accordance with the approved procedure for quality control. If each forged wheel is individually controlled by an approved non-destructive examination method, then no overspeed test may be required except for wheels of the test unit.

12.3.7 A mechanical running test, *see* Pt 9, Ch 2,3.4, is to be carried out. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbo-chargers. For manufacturers who have facilities in their works for testing the turbo-chargers on an engine for which the turbo-chargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110 per cent of the rated output) on this engine.

12.4 Compliance and certificate

12.4.1 For every turbo-charger unit liable to be installed on an engine intended for a ship classed by LR, the manufacturer is to supply a statement certifying that the turbo-charger is identical with one that underwent the tests specified in 12.2.4 and that prescribed tests were carried out. Results of these tests are also to be stated. This statement is to be made on a form agreed with LR and a copy is to be sent to LR. Each statement must have a number which is to appear on the turbo-charger.

Section 13
Electronically controlled engines

13.1 Scope

13.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency power purposes with programmable electronic systems implemented and used to control fuel injection timing and duration, and which may also control combustion air or exhaust systems. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

13.1.2 These engines may be of the slow, medium or high-speed type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

13.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

13.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the Enginebuilder.

13.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

13.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

13.2 Plans and particulars

13.2.1 In addition to the plans and particulars required by Section 2 the following information is to be submitted:

(a) A general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

(b) Operating manuals which describe the particulars of each system and, together with maintenance instructions, include reference to the functioning of sub-systems.

(c) A risk-based analysis of the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. The analysis is to demonstrate that suitable risk mitigation has been achieved in accordance with 13.3.

(d) Details of hydraulic systems for actuation of subsystems (fuel injection or exhaust), to include details of the design/ construction of pipes, pumps, valves, accumulators and the control of valves/pumps. Details of pump drive arrangements are also to be included.

(e) Quality plan for sourcing, design, installation and testing of all components used in the oil fuel and hydraulic oil systems installed with the engine for engine operation.

(f) Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

(g) Evidence of type testing of the engine with the programmable electronic system, or a proposed test plan at the Enginebuilders with the programmable electronic system functioning, to verify the functionality and behaviour under all operating and fault conditions of the programmable electronic system.

(h) Schedule of testing at Enginebuilders, pre-sea trial commissioning and sea trials. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under the intended engine operating modes. The schedule is to include:
(i) testing and trials to demonstrate that the engine is capable of operating as described in (a);
(ii) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
(iii) testing required to verify the conclusions of the risk-based analysis.

The scope of these tests is to be agreed with LR.

13.2.2 In addition to the applicable plans and particulars required by Pt 16, Ch 1,1.2.3 to 1.2.6 the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see* 13.5.2;
(b) Software quality plans, including configuration management documents;
(c) Software safety evidence; and
(d) Software assessment inspection report.

13.3 Risk-based analysis

13.3.1 An analysis is to be carried out in accordance with relevant standards acceptable to LR to demonstrate compliance with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and craft and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in 13.3.2 to 13.3.4 relevant to the engine application.

13.3.2 For craft with a single main propulsion engine, a Failure Mode and Effects Analysis (FMEA), or alternative recognised analysis of system reliability, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see* Pt 16, Ch 1,2.5.11 and 2.12.2;

(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see* Pt 16, Ch 1,2.13.4 and 2.13.5; and

(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the craft in an unsafe condition, *see* Pt 16, Ch 1,2.3.14, 2.4.6, 2.5.5, 2.10.3, 2.10.4 and 2.13.5.

13.3.3 A risk-based analysis is to be carried out for:

(a) main engines on craft with multiple main engines or other means of providing propulsion power; and/or

(b) auxiliary engines intended to drive electric generators forming the craft's main source of electrical power or otherwise providing power for essential services.

The analysis is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall craft installation with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the craft. Arrangements satisfying the criteria of 13.3.2(a) to (c) will also be acceptable.

13.3.4 For engines for emergency power purposes, a risk-based analysis is to be carried out to demonstrate that the design incorporates adequate hazard mitigation, such that the likelihood of an electronic control system failure, resulting in the loss of the ability to provide emergency power when required, has been reduced to a level considered acceptable by LR, and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified, and the report is to include documentation of:

(a) component reliability evidence;

(b) failure detection and alarms; and

(c) failure response required to restore engine availability and maintain personnel safety.

13.3.5 The risk-based analysis report is to:

(a) Identify the standards used for analysis and system design;

(b) Identify the engine, its purpose and the associated objectives of the analysis;

(c) Identify any assumptions made in the analysis.;

(d) Identify the equipment, system or sub-system, mode of operation and the equipment;

(e) Identify potential failure modes and their causes.

(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode;

(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.); and

(h) Identify trials and testing necessary to prove conclusions.

13.3.6 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

13.4 Oil fuel and hydraulic oil systems

13.4.1 Oil fuel and hydraulic oil piping system arrangements are to comply with Part 15 as applicable.

13.4.2 Where pumps are essential for engine operation, no fewer than two oil fuel and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each oil fuel pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

13.4.3 The oil fuel pressure piping between the oil fuel high pressure pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing oil fuel leakage from a high pressure pipe failure.

13.4.4 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system capable of containing hydraulic oil leakage from a high pressure pipe failure.

13.4.5 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

13.4.6 All valves, cocks and screwed connections are to be of a type-tested type applicable to the maximum service conditions anticipated in normal service.

13.4.7 Isolating valves and cocks are to be located as near as practicable to the equipment to be isolated. All valves forming part of the oil fuel and hydraulic oil installation are to be capable of being controlled from readily accessible positions above the working platform.

13.4.8 High pressure oil fuel and high pressure hydraulic oil piping systems are to be provided with high pressure alarms with set points that do not exceed the system design pressures.

13.4.9 High pressure oil fuel and high pressure hydraulic piping systems are to be provided with suitable relief valves on any part of the system that can be isolated and in which pressure can be generated. The settings of the relief valves are not to exceed the design pressures. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressures.

13.4.10 Equipment fitted for monitoring pressures and temperatures in the high pressure oil fuel and high pressure hydraulic oil systems is to comply with a recognised standard suitable to the anticipated vibration and temperature conditions.

13.4.11 A fatigue analysis is to be carried out in accordance with a standard applicable to the system under consideration and all anticipated pressure, pulsation and vibration loads are to be addressed. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing of the system. Any potential weak points which may develop due to incorrect construction or assembly are also to be identified.

13.4.12 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues:

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

13.5 Control engineering systems

13.5.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with Pt 16, Ch 1 as applicable.

13.5.2 The engine control, alarm monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and Pt 16, Ch 1 for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration, identifying:

(a) Local and remote means to carry out system configuration.
(b) Enginebuilder procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g. Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion, auxiliary or emergency engine application.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with Pt 16, Ch 1,1.4 and 7.1.3.

13.6 Software

13.6.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* Pt 16, Ch 1,2.12.2 and 2.12.7.

13.6.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the Enginebuilder. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

13.6.3 To demonstrate compliance with 13.6.1 and 13.6.2:

(a) software quality plans and safety evidence are to be submitted for consideration, *see* 13.2.2(b) and (c); and
(b) an assessment inspection of the Enginebuilder's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

■ *Section 14* Programme for trials of diesel engines to assess operational capability

14.1 Works trials (acceptance test)

14.1.1 Diesel engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in 14.1.2 to 14.1.10. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.

14.1.2 For electronically controlled engines:

(a) works tests in accordance with 13.2.1(h); and
(b) verification of engine configuration, *see* 13.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

14.1.3 For all stages of the works trials, the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer.

14.1.4 In each case given in Table 1.14.1, all measurements conducted at the various load points shall be carried out at steady operating conditions. The readings for 100 per cent power (rated power at rated speed) are to be taken twice at an interval of at least 30 minutes.

14.1.5 The data to be measured and recorded, when testing the engine at various load points, are to include all necessary parameters for the engine operation. The crankshaft deflection is to be checked when this check is required by the manufacturer during the operating life of the engine. Crankshaft deflection measurements are to be taken before (cold condition) and after (hot condition) works acceptance trials.

Table 1.14.1 Scope of works trials for diesel engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 60 minutes	After having reached steady conditions
110 per cent power at engine speed corresponding to 1,032**R*	30–45 minutes	After having reached steady conditions (1)
90 per cent (or maximum continuous power), 75 per cent, 50 per cent and 25 per cent	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.2
Shut-down device	—	*See* 9.4
Engines driving generators		
Trial condition	Duration	Note
100 per cent power (rated power) at rated engine speed, *R*	≥ 50 minutes	After having reached steady conditions (2)
110 per cent power	15 minutes	After having reached steady conditions (2) (3)
75 per cent, 50 per cent and 25 per cent power and idle run	—	(2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See* 9.3
Shut-down device	—	*See* 9.4

NOTES
1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service.
2. The test is to be performed at rated speed with a constant governor setting.
3. After running on the test bed, the fuel delivery system of diesel engines driving generators must be adjusted such that overload (110 per cent) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.

14.1.6 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

14.1.7 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

14.1.8 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

14.1.9 The testing of exhaust gas emissions is to comply with MARPOL as applicable.

14.1.10 For all stages that the engine is to be tested and where no duration is specified in Table 1.14.1, the load point is to be maintained for a sufficient period to allow pertaining values to be measured and recorded when the engine has achieved a steady operating condition.

14.2 On board trials

14.2.1 After the conclusion of the running-in programme prescribed by the engine manufacturer, engines are to undergo on board trials as specified in Table 1.14.2. The scope of the trials is to be agreed between the LR Surveyor and the Builder prior to testing.

Table 1.14.2 Scope of shipboard trials for diesel engines

Main engines driving fixed-pitch propellers (1) (2)		
Trial condition	Duration	Note
At rated engine speed, *R*	≥ 4 hours	—
At engine speed corresponding to normal continuous power	≥ 2 hours	—
At engine speed corresponding to 1,032**R*	30 minutes	Where the engine adjustment permits, *see* 14.1.7
At minimum on-load speed	—	—
Starting and reversing manoeuvres	—	*See* Ch 1,7
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7**R*	10 minutes	—
Control, monitoring, alarms and safety systems	—	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	—	—
Single engine driving generator for propulsion only		
Trial condition	Duration	Note
100% power (rated propulsion power), *see* 14.2.3	≥ 4 hours	(3) (4)
At normal continuous propulsion power	≥ 2 hours	(3) (4)
110% power (rated propulsion power)	30 minutes	
In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed	10 minutes	(3) (4)
Starting manoeuvres	—	—
Control, monitoring, alarm and safety systems	—	Operation to be demonstrated

NOTES
1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate.
2. Controllable pitch propellers are to be tested with various propeller pitches.
3. The tests to be performed at rated speed with a constant governor setting.
4. Tests are to be based on the rated electrical powers of the electric propulsion motors.

14.2.2 Engines driving generators or important auxiliaries are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of on board generating sets, account shall be taken of the times needed to actuate the generator's overload protection system

14.2.3 In addition to 14.2.2, for engines driving generators for electric propulsion motors as well as auxiliaries, an operational test is to be carried out of at least 4 hours duration at a load which corresponds to 100 per cent of the electric propulsion motor(s) rated power. The astern/ahead manoeuvring capability of the propulsion system is to be demonstrated.

14.2.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines.

14.2.5 For electronically controlled engines:
(a) On board tests in accordance with 13.2.1(h); and
(b) verification of engine configuration, *see* 13.5.2, and that the approved software quality plans, including the software configuration management process, are being applied.

14.2.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated, if the machinery installation is arranged to burn such fuels in service. *See also* Pt 16, Ch 1,7.2.1.

14.2.7 At the discretion of the attending Surveyor, the scope of the trials may be expanded in consideration of special operating conditions, such as towing, trawling, etc.

■ *Section 15* Type testing procedure for crankcase explosion relief valves

15.1 Scope

15.1.1 To specify type tests and identify standard test conditions using methane gas and air mixture to demonstrate that LR requirements are satisfied for crankcase explosion relief valves intended to be fitted to engines and gear cases.

15.1.2 The test procedure is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for approval.

15.2 Purpose

15.2.1 The purpose of type testing crankcase explosion relief valves is fourfold:

(a) To verify the effectiveness of the flame arrester.
(b) To verify that the valve closes after an explosion.
(c) To verify that the valve is gas/air tight after an explosion.
(d) To establish the level of over-pressure protection provided by the valve.

15.3 Test facilities

15.3.1 Test houses for carrying out type testing of crankcase explosion relief valves are to meet the following requirements:

(a) The test houses where testing is carried out are to be accredited to a National or International Standard for the testing of explosion protection devices, such as ISO/IEC 17025.
(b) The test facilities are to be acceptable to LR.
(c) The test facilities are to be equipped so that they can perform and record explosion testing in accordance with this procedure.
(d) The test facilities are to have equipment for controlling and measuring a methane gas in air concentration within a test vessel to an accuracy of ±0,1 per cent.
(e) The test facilities are to be capable of effective point-located ignition of a methane gas in air mixture.
(f) The pressure measuring equipment is to be capable of measuring the pressure in the test vessel in at least two positions, one at the valve and the other at the test vessel centre. The measuring arrangements are to be capable of measuring and recording the pressure changes throughout an explosion test at a frequency recognising the speed of events during an explosion. The result of each test is to be documented by video recording and by recording with a heat sensitive camera.
(g) The test vessel for explosion testing is to have documented dimensions. The dimensions are to be such that the vessel is not pipe-like with the distance between dished ends being not more than 2,5 times the diameter. The internal volume of the test vessel is to include any standpipe arrangements.
(h) The test vessel is to be provided with a flange, located centrally at one end at 90° to the vessel longitudinal axis for mounting the explosion relief valve. The test vessel is to be arranged in an orientation consistent with how the valve will be installed in service, i.e., in the vertical plane or the horizontal plane.
(j) A circular flat plate is to be provided for fitting between the pressure vessel flange and valve to be tested with the following dimensions:
    1. Outside diameter of 2 times the outer diameter of the valve top cover.
    2. Internal bore having the same internal diameter as the valve is to be tested.
(k) The test vessel is to have connections for measuring the methane in air mixture at the top and bottom.
(l) The test vessel is to be provided with a means of fitting an ignition source at a position as specified in 15.4.3.
(m) The test vessel volume is to be as far as practicable, related to the size and capability of the relief valve to be tested. In general, the volume is to correspond to the requirement in 6.3.1 for the free area of explosion relief valve to be not less than 115 cm^2/m^3 of crankcase gross volume, e.g., the testing of a valve having 1150 cm^2 of free area, would require a test vessel with a volume of 10 m^3. The following is to apply:
    (i) Where the free area of relief valves is greater than 115 cm^2/m^3 of the crankcase gross volume, the volume of the test vessel is to be consistent with the design ratio.
    (ii) In no case is the volume of the test vessel to vary by more than ±15 per cent from the design cm^2/m^3 volume ratio.

15.4 Explosion test process

15.4.1 All explosion tests to verify the functionality of crankcase explosion relief valves are to be carried out using an air and methane mixture with a volumetric methane concentration of 9,5 per cent ±0,5 per cent. The pressure in the test vessel is to be not less than atmospheric and is not to exceed the opening pressure of the relief valve.

15.4.2 The concentration of methane in the test vessel is to be measured at the top and bottom of the vessel and these concentrations are not to differ by more than 0,5 per cent.

15.4.3 The ignition of the methane and air mixture is to be made at the centreline of the test vessel at a position approximately one third of the height or length of the test vessel opposite to where the valve is mounted.

15.4.4 The ignition is to be made using a maximum 100 joule explosive charge.

15.5 Valves to be tested

15.5.1 The valves used for type testing (including the testing specified in 15.5.3) are to be selected from the manufacturer's normal production line for such valves by the LR Surveyor witnessing the tests.

15.5.2 For approval of a specific valve size, three valves are to be tested in accordance with 15.5.3 and 15.6. For a series of valves, *see* 15.8.

15.5.3 The valves selected for type testing are to have been previously tested at the manufacturer's works to demonstrate that the opening pressure is in accordance with the specification within a tolerance of ±20 per cent and that the valve is air tight at a pressure below the opening pressure for at least 30 seconds. This test is to verify that the valve is air tight following assembly at the manufacturer's works and that the valve begins to open at the required pressure demonstrating that the correct spring has been fitted.

15.5.4 The type testing of valves is to recognise the orientation in which they are intended to be installed on the engine or gear case. Three valves of each size are to be tested for each intended installation orientation, i.e. in the vertical and/or horizontal positions.

15.6 Method

15.6.1 The following requirements are to be satisfied at explosion testing:

(a) The explosion testing is to be witnessed by a LR surveyor.
(b) Where valves are to be installed on an engine or gear case with shielding arrangements to deflect the emission of explosion combustion products, the valves are to be tested with the shielding arrangements fitted.
(c) Successive explosion testing to establish a valve's functionality is to be carried out as quickly as possible during stable weather conditions.
(d) The pressure rise and decay during all explosion testing is to be recorded.
(e) The external condition of the valves is to be monitored during each test for indication of any flame release by video and heat sensitive camera.

15.6.2 The explosion testing is to be in three stages for each valve that is required to be approved as being type tested.

15.6.3 **Stage 1.** Two explosion tests are to be carried out in the test vessel with the circular plate as specified in 15.3.1(j) fitted and the opening in the plate covered by a 0,05 mm thick polythene film. These tests establish a reference pressure level for determination of the capability of a relief valve in terms of pressure rise in the test vessel, *see* 15.7.1(f).

15.6.4 **Stage 2.**

(a) Two explosion tests are to be carried out on three different valves of the same size. Each valve is to be mounted in the orientation for which approval is sought, i.e., in the vertical or horizontal position with the circular plate described in 15.3.1(j) located between the valve and pressure vessel mounting flange.
(b) The first of the two tests on each valve is to be carried out with a 0,05 mm thick polythene bag, having a minimum diameter of three times the diameter of the circular plate and volume not less than 30 per cent of the test vessel, enclosing the valve and circular plate. Before carrying out the explosion test the polythene bag is to be empty of air. The polythene bag is required to provide a readily visible means of assessing whether there is flame transmission through the relief valve following an explosion. During the test, the explosion pressure will open the valve and some unburned methane/air mixture will be collected in the polythene bag. When the flame reaches the flame arrester and if there is flame transmission through the flame arrester, the methane/air mixture in the bag will be ignited and this will be visible.
(c) Provided that the first explosion test successfully demonstrated that there was no indication of combustion outside the flame arrester and there are no signs of damage to the flame arrester or valve, a second explosion test without the polythene bag arrangement is to be carried out as quickly as possible after the first test. During the second explosion test, the valve is to be visually monitored for any indication of combustion outside the flame arrester and video records are to be kept for subsequent analysis. The second test is required to demonstrate that the valve can still function in the event of a secondary crankcase explosion.
(d) After each explosion, the test vessel is to be maintained in the closed condition for at least 10 seconds to enable the tightness of the valve to be ascertained. The tightness of the valve can be verified during the test from the pressure/time records or by a separate test after completing the second explosion test.

15.6.5 **Stage 3.** Carry out two further explosion tests as described in Stage 1. These further tests are required to provide an average baseline value for assessment of pressure rise, recognising that the test vessel ambient conditions may have changed during the testing of the explosion relief valves in Stage 2.

15.7 Assessment and records

15.7.1 For the purposes of verifying compliance with the requirements of this Section, the assessment and records of the valves used for explosion testing is to address the following:

(a) The valves to be tested are to have evidence of appraisal/approval by LR, *see also* 15.5.1.
(b) The designation, dimensions and characteristics of the valves to be tested are to be recorded. This is to include the free area of the valve and of the flame arrester, and the amount of valve lift at 0,2 bar.
(c) The test vessel volume is to be determined and recorded.
(d) For acceptance of the functioning of the flame arrester there is not to be any indication of flame or combustion outside the valve during an explosion test.
(e) The pressure rise and decay during an explosion is to be recorded, with indication of the pressure variation showing the maximum overpressure and steady under-pressure in the test vessel during testing. The pressure variation is to be recorded at two points in the pressure vessel.
(f) The effect of an explosion relief valve in terms of pressure rise following an explosion is ascertained from maximum pressures recorded at the centre of the test vessel during the three stages. The pressure rise within the test vessel due to the installation of a relief valve is the difference between average pressure of the four explosions from Stages 1 and 3 and the average of the first tests on the three valves in Stage 2. The pressure rise is not to exceed the limit specified by the manufacturer.
(g) The valve tightness is to be ascertained by verifying from the records at the time of testing that an under-pressure of at least 0,3 bar is held by the test vessel for at least 10 seconds following an explosion. This test is to verify that the valve has effectively closed and is reasonably gas-tight following dynamic operation during an explosion.
(h) After each explosion test in Stage 2, the external condition of the flame arrester is to be examined for signs of serious damage and/or deformation that may affect the operation of the valve.
(j) After completing the explosion tests, the valves are to be dismantled and the condition of all components ascertained and documented. In particular, any indication of valve sticking or uneven opening that may affect the operation of the valve is to be noted. Photographic records of the valve condition are to be taken and included in the report.

15.8 Design series qualification

15.8.1 The qualification of quenching devices to prevent the passage of flame can be evaluated for other similar devices of identical type where one device has been tested and found satisfactory.

15.8.2 The quenching ability of a flame arrester depends on the total mass of quenching lamellas/mesh. Provided the materials, thickness of materials, length of lamellas/thickness of mesh layer and the quenching gaps are the same, then the same quenching ability can be qualified for different sizes of flame arresters subject to (a) and (b) being satisfied.

(a) $$\frac{n_1}{n_2} = \sqrt{\frac{S_1}{S_2}}$$

(a) $$\frac{A_1}{A_2} = \frac{S_1}{S_2}$$

where

n_1 = total depth of flame arrester corresponding to the number of lamellas of size 1 quenching device for a valve with a relief area equal to S_1
n_2 = total depth of flame arrester corresponding to the number of lamellas of size 2 quenching device for a valve with a relief area equal to S_2
A_1 = free area of quenching device for a valve with a relief area equal to S_1
A_2 = free area of quenching device for a valve with a relief area equal to S_2.

15.8.3 The qualification of explosion relief valves of larger sizes than that which has been previously satisfactorily tested in accordance with 15.6 and 15.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a larger valve does not exceed three times + 5 per cent that of the valve that has been satisfactorily tested.
(b) One valve of the largest size, subject to (a), requiring qualification is subject to satisfactory testing required by 15.5.3 and 15.6.4 except that a single valve will be accepted in 15.6.4(a) and the volume of the test vessel is not to be less than one third of the volume required by 15.3.1(m).
(c) The assessment and records are to be in accordance with 15.7, noting that 15.7.1(f) will only be applicable to Stage 2 for a single valve.

15.8.4 The qualification of explosion relief valves of smaller sizes than that which has been previously satisfactorily tested in accordance with 15.6 and 15.7 can be evaluated where valves are of identical type and have identical features of construction subject to the following:

(a) The free area of a smaller valve is not less than one third of that of the valve that has been satisfactorily tested.
(b) One valve of the smallest size, subject to (a), requiring qualification is subject to satisfactory testing required by 15.5.3 and 15.6.4 except that a single valve will be accepted in 15.6.4(a) and the volume of the test vessel is not to be more than the volume required by 15.3.1(m).
(c) The assessment and records are to be in accordance with 15.7, noting that 15.7.1(f) will only be applicable to Stage 2 for a single valve.

15.9 The report

15.9.1 The test house is to deliver a full report that includes the following information and documents:

(a) Test specification.
(b) Details of test pressure vessel and valves tested.
(c) The orientation in which the valve was tested (vertical or horizontal position).
(d) Methane in air concentration for each test.
(e) Ignition source.
(f) Pressure curves for each test.
(g) Video recordings of each valve test.
(h) The assessment and records stated in 15.7.

15.10 Approval

15.10.1 The approval of an explosion relief valve is at the discretion of LR, based on the appraisal of plans and particulars and the test facility's report of the results of type testing.

■ *Section 16* **Type testing procedure for crankcase oil mist detection and alarm equipment**

16.1 Scope

16.1.1 To specify the tests required to demonstrate that crankcase oil mist detection and alarm equipment intended to be fitted to diesel engines satisfy LR requirements.

16.1.2 This test procedure is also applicable to oil mist detection and alarm arrangements intended for gear cases.

16.2 Purpose

16.2.1 The purpose of type testing crankcase oil mist detection and alarm equipment is sevenfold:

(a) To verify the functionality of the system.
(b) To verify the effectiveness of the oil mist detectors.
(c) To verify the accuracy of the oil mist detectors.
(d) To verify the alarm set points.
(e) To verify time delays between oil mist leaving the source and alarm activation.
(f) To verify functional failure detection.
(g) To verify the influence of optical obscuration on detection.

16.3 Test facilities

16.3.1 Test houses carrying out type testing of crankcase oil mist detection and alarm equipment are to satisfy the following criteria:

(a) A full range of facilities for carrying out the environmental and functionality tests required by this procedure shall be available and be acceptable to LR.
(b) The test house that verifies the functionality of the equipment is to be equipped so that it can control, measure and record oil mist concentration levels in terms of mg/l to an accuracy of ±10 per cent in accordance with this procedure.

16.4 Equipment testing

16.4.1 The range of tests is to include the following for the alarm/monitoring panel:

(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations, if moving parts are contained.

16.4.2 The range of tests is to include the following for the detectors:

(a) Functional tests described in 16.5.
(b) Electrical power supply failure test.
(c) Power supply variation test.
(d) Dry heat test.
(e) Damp heat test.
(f) Vibration test.
(g) EMC test.
(h) Insulation resistance test.
(j) High voltage test.
(k) Static and dynamic inclinations.

16.5 Functional tests

16.5.1 All tests to verify the functionality of crankcase oil mist detection and alarm equipment are to be carried out in accordance with 16.5.2 to 16.5.6 with an oil mist concentration in air, known in terms of mg/l to an accuracy of ±10 per cent.

16.5.2 The concentration of oil mist in the test chamber is to be measured in the top and bottom of the chamber and these concentrations are not to differ by more than 10 per cent. *See* 16.7.2(a).

16.5.3 The oil mist monitoring arrangements are to be capable of detecting oil mist in air concentrations of between 0 and 10 per cent of the lower explosive limit (LEL), which corresponds to an oil mist concentration of approximately 50 mg/l (15 per cent oil-air mixture) or between 0 and a percentage corresponding to a level not less than twice the maximum oil mist concentration alarm set point.

16.5.4 The alarm set point for oil mist concentration in air is to provide an alarm at a maximum setting corresponding to not more than 5 per cent of the LEL or approximately 2,5mg/l.

16.5.5 Where alarm set points can be altered, the means of adjustment and indication of set points are to be verified against the equipment manufacturer's instructions.

16.5.6 Where oil mist is drawn into a detector via piping arrangements, the time delay between the sample leaving the crankcase and operation of the alarm is to be determined for the longest and shortest lengths of pipes recommended by the manufacturer. The pipe arrangements are to be in accordance with the manufacturer's instructions/recommendations.

16.5.7 Detector equipment that is in contact with the crankcase atmosphere and may be exposed to oil splash and spray from engine lubricating oil is to be tested to demonstrate that openings do not occlude or become blocked under continuous oil splash or spray conditions. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR.

16.5.8 Detector equipment may be exposed to water vapour from the crankcase atmosphere which may affect the sensitivity of the equipment. It is to be demonstrated that exposure to such conditions will not affect the functional operation of the detector equipment. Where exposure to water vapour and/or water condensation has been identified as a possible source of equipment malfunctioning, testing is to demonstrate that any mitigating arrangements such as heating are effective. Testing is to be in accordance with arrangements proposed by the manufacturer and agreed by LR. This testing is in addition to that required by 16.4.2(e) and is concerned with the effects of condensation caused by the detection equipment being at a lower temperature than the crankcase atmosphere.

16.6 Detectors and alarm equipment to be tested

16.6.1 The detectors and alarm equipment selected for the type testing are to be selected from the manufacturer's normal production line by the LR Surveyor witnessing the tests.

16.6.2 Two detectors are to be tested. One is to be tested in the clean condition and the other in a condition representing the maximum level of lens obscuration specified by the manufacturer.

16.7 Method

16.7.1 The requirements of 16.7 are to be satisfied at type testing.

16.7.2 Oil mist generation is to satisfy the following:

(a) Oil mist is to be generated with suitable equipment using an SAE 80 monograde mineral oil or equivalent and supplied to a test chamber having a volume of not less than 1 m^3. The oil mist produced is to have a maximum droplet size of 5 μm. The oil droplet size is to be checked using the sedimentation method.

(b) The oil mist concentrations used are to be ascertained by the gravimetric deterministic method or equivalent. For this test, the gravimetric deterministic method is a process where the difference in weight of a 0,8 μm pore size membrane filter is ascertained from weighing the filter before and after drawing 1 litre of oil mist through the filter from the oil mist test chamber. The oil mist chamber is to be fitted with a recirculating fan.

(c) Samples of oil mist are to be taken at regular intervals and the results plotted against the oil mist detector output. The oil mist detector is to be located adjacent to where the oil mist samples are drawn off.

(d) The results of a gravimetric analysis are considered invalid and are to be rejected if the resultant calibration curve has an increasing gradient with respect to the oil mist detection reading. This situation occurs when insufficient time has been allowed for the oil mist to become homogeneous. Single results that are more than 10 per cent below the calibration curve are to be rejected. This situation occurs when the integrity of the filter unit has been compromised and not all of the oil is collected on the filter paper.

(e) The filters require to be weighed to a precision of 0,1 mg and the volume of air/oil mist sampled to 10 ml.

16.7.3 The testing is to be witnessed by an LR Surveyor where type testing approval is required by LR.

16.7.4 Oil mist detection equipment is to be tested in the orientation (vertical, horizontal or inclined) in which it is intended to be installed on an engine or gear case as specified by the equipment manufacturer.

16.7.5 Type testing is to be carried out for each type of oil mist detection and alarm equipment for which a manufacturer seeks LR approval. Where sensitivity levels can be adjusted, testing is to be carried out at the extreme and mid-point level settings.

16.8 Assessment

16.8.1 Assessment of oil mist detection equipment after testing is to address the following:

(a) The equipment to be tested is to have evidence of design appraisal/approval by LR, *see also* 16.6.1.

(b) Details of the detection equipment to be tested are to be recorded such as name of manufacturer, type designation, oil mist concentration assessment capability and alarm settings.

(c) After completing the tests, the detection equipment is to be examined and the condition of all components ascertained and documented. Photographic records of the monitoring equipment condition are to be taken and included in the report.

16.9 Design series qualification

16.9.1 The approval of one type of detection equipment may be used to qualify other devices having identical construction details. Proposals are to be submitted for consideration.

16.10 The report

16.10.1 The test house is to provide a full report which includes the following information and documents:

(a) Test specification.
(b) Details of equipment tested.
(c) Results of tests.

16.11 Acceptance

16.11.1 Acceptance of crankcase oil mist detection equipment is at the discretion of LR, based on the appraisal of plans and particulars and the test house report of the results of type testing.

16.11.2 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.
(b) Copy of the test house report identified in 16.10.
(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.
(d) Maintenance and test manual which is to include the following information:
    - Intended use of equipment and its operation.
    - Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified.
    - Maintenance routines and spare parts recommendations.
    - Limit setting and instructions for safe limit levels.
    - Where necessary, details of configurations in which the equipment is and is not to be used.

Section 1
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter are applicable to gas turbines for main propulsion and essential auxiliary services.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Power conditions for generator sets

1.3.1 Auxiliary gas turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see* Pt 16, Ch 2.

1.4 Inclination of craft

1.4.1 Main and essential auxiliary gas turbines are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

Section 2
Particulars to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans are to be submitted:

- Sectional assembly.
- Casings.
- Combustion chambers and heat exchangers.
- Rotors, bearings and couplings.
- Blades and blade attachments.
- Inlet and exhaust ducting.
- Securing arrangement (including details of resilient mounts where applicable).
- Control engineering aspects in accordance with Pt 16, Ch 1.
- Fuel oil system schematic, including controls and safety devices.
- Lubricating oil system schematic.
- Starting system schematic.
- Cooling water system schematic, where applicable.

2.1.2 The following information and calculations are to be submitted:

(a) Details of the acoustic enclosure fire detection and extinguishing system, where applicable.

(b) Power/speed operational envelope.
Calculations and information for short term high power operation, where applicable.
Operation and Maintenance Manuals.

(c) Calculations of the critical speeds of blade and rotor vibration, giving full details of the basic assumptions.
An analysis of the effect of a rotor blade failure and any details of service experience, *see* 4.3.

(d) High temperature characteristics of the materials, where applicable, including (at the working temperatures) the associated creep rate and rupture strength for the designed service life, fatigue strength, corrosion resistance and scaling properties.
Particulars of heat treatment, including stress relief, where applicable.
Material specifications covering the listed components together with details of any surface treatments, non-destructive testing and hydraulic tests.

2.1.3 The most onerous pressures and temperatures to which each component may be subjected are to be indicated on plans or provided as part of the design specification.

2.1.4 Calculations of the steady state stresses, including the effect of stress raisers, etc., in the turbine and compressor rotors and blading at the maximum speed and temperature in service are to be submitted. Such calculations should indicate the designed service life and be accompanied, where possible, by test results substantiating the limiting criteria.

2.1.5 Details of calculations and tests to establish the service life of other stressed parts, including gearing (where applicable), bearings, seals, etc., are also to be submitted. All calculations and tests should take account of all relevant environmental factors including particular type of service and fuel intended to be used.

2.1.6 Components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding of the standards appropriate to the components. Details are to be submitted for consideration.

2.1.7 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

2.1.8 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration.

2.1.9 A Failure Mode and Effects Analysis (FMEA) is to be submitted as detailed in Part 9.

■ *Section 3* Materials

3.1 Materials for forgings

3.1.1 Rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2. *See also Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 For alloy steels, specifications giving the proposed chemical composition and heat treatment are to be submitted for approval.

3.1.3 When it is proposed to use a material of higher tensile strength, full details are to be submitted for approval.

3.1.4 Components of non-ferrous construction should be submitted for consideration, together with full details of materials to be used and method of fabrication.

3.2 Material tests and inspection

3.2.1 Components are to be tested in accordance with the relevant requirements of the Rules for Materials.

3.2.2 For components of novel design special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 4* Design

4.1 General

4.1.1 All parts of turbines, compressors, etc., are to have clearances and fits consistent with adequate provision for the relative thermal expansion of the various components. Special attention is to be given to minimising casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

4.2 Vibration

4.2.1 Care is to be taken in the design and manufacture of turbine and compressor rotors, rotor discs and rotor blades to ensure freedom from undue vibration within the operating speed range. Where critical speeds are found by calculation to occur within the operating speed range, vibration measurements may be requested in order to verify the calculations, *see* Part 13.

4.3 Containment

4.3.1 Gas turbines are to be designed and installed so as to contain debris in the event of an internal failure.

4.3.2 The gas turbine is to be located such that any flying debris resulting from a failure will not endanger the craft, other machinery, occupants of the craft or any other persons.

4.3.3 Where an acoustic enclosure is fitted which completely surrounds the gas generator and the high pressure oil pipes, a fire detection and extinguishing system is to be provided for the acoustic enclosure.

4.4 External influences

4.4.1 Pipes and ducting connected to casings are to be so designed that no excessive thrust loads or moments are applied by them to the compressors and turbines.

4.4.2 Platform gratings and fittings in way of the supports are to be so arranged that casing expansion is not restricted.

4.4.3 Where main turbine seatings incorporating a tank structure are proposed, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.4.4 For securing arrangements, including resilient mounting, *see* Pt 9, Ch 1.

Section 5
Construction

5.1 Welded components

5.1.1 All welded construction is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.1.2 Major joints are to be designed as full-strength welds and for complete fusion of the joint.

5.1.3 Stress relief heat treatment is to be applied to all cylinders, rotors and associated components on completion of the welding of all joints and attached structures, *see* Part 15.

Section 6
Starting arrangements

6.1 Initial starting arrangements

6.1.1 Equipment for starting main and auxiliary turbines is to be provided and arranged such that the necessary initial charge of starting air or initial electric power can be developed on board the craft without external aid. If for this purpose an emergency air compressor or electric generator is required, these units are to be power driven by manually started oil engines except in the case of small installations where a hand operated compressor of approved capacity may be accepted. Alternatively, other devices of approved type may be accepted as a means of providing the initial start, *see also* Pt 16, Ch 2,2.4.2.

6.2 Purging before ignition

6.2.1 Means are to be provided, preferably automatic or interlocked, to clear all parts of the gas turbine of the accumulation of oil fuel or for purging gaseous fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

6.3 Air starting

6.3.1 Where the gas turbine is arranged for air starting the total air receiver capacity is to be sufficient to provide, without replenishment, not less than six consecutive starts. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see* Part 15.

6.3.2 For multi-engine installations three consecutive starts per engine are required.

6.4 Electric starting

6.4.1 Where main turbines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the turbines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main turbines as required by 6.3.

6.4.2 Electric starting arrangements for auxiliary turbines are to have two separate batteries or be supplied by separate circuits from the main turbine batteries when such are provided. Where one of the auxiliary turbines only is fitted with an electric starter one battery will be acceptable.

6.4.3 The combined capacity of the batteries for starting the auxiliary turbines is to be sufficient for at least three starts for each turbine.

6.4.4 The requirements for battery installations are given in Pt 16, Ch 2.

Section 7
Piping systems

7.1 General

7.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in Pt 15, Ch 1 and Ch 3, due regard being paid to the particular type of installation.

7.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in compressed air, fresh water, sea-water, oil fuel and lubricating oil systems. Where synthetic rubber hoses are used for fuel or supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid.

7.2 Oil fuel systems

7.2.1 Oil fuel arrangements are to comply with the requirements of Pt 15, Ch 3.

7.2.2 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary turbines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the turbines.

7.3 Lubricating oil systems

7.3.1 Lubricating oil arrangements are to comply with the requirements of Pt 15, Ch 3.

7.3.2 Where the lubricating oil for main propelling gas turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

7.4 Cooling systems

7.4.1 Cooling water arrangements are to comply with the requirements of Pt 15, Ch 3, as applicable.

7.5 Inlet and exhaust systems

7.5.1 The air-inlet system is to be designed to minimise the ingestion of harmful particles. Icing up of air intakes is to be prevented.

7.5.2 Means for preventing the accumulation of salt deposits in the compressors and turbines, e.g. water washing, are to be provided.

7.5.3 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

7.5.4 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self draining overboard. Erosion/corrosion resistant shut off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space.

7.5.5 Where two or more turbines have a common exhaust, an isolating device is to be provided in each exhaust pipe.

7.5.6 The exhaust system is to be arranged so that hot exhaust gases are directed away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

■ *Section 8*
Control and monitoring

8.1 General

8.1.1 Control engineering systems are to comply with the requirements of Part 16.

8.2 Overspeed protective devices

8.2.1 An overspeed protective device is to be provided for each shaft of main and auxiliary turbines to automatically shut off the fuel, near the burners, to prevent a dangerous overspeed condition of the shaft, unless it can be established that such a condition cannot arise.

8.2.2 The overspeed device is to be set to operate before the speed of the line exceeds the rated maximum speed by 10 per cent. For auxiliary turbines driving electric generators this setting may be increased to 15 per cent.

8.3 Speed governors

8.3.1 Where a main propulsion installation incorporates a reverse gear, electric transmission or controllable (reversible) pitch propeller, a speed governor, independent of the overspeed protective device, is to be fitted and is to be capable of controlling the speed of the unloaded power turbine without bringing the overspeed protective device into action.

8.3.2 Where an auxiliary turbine is intended for driving an electric generator, a speed governor, independent of the overspeed protective device, is to be fitted which, with fixed setting, is to control the speed within 10 per cent momentary variation and five per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of a.c. machines intended for parallel operations are to be equal within a tolerance of ±0,5 per cent.

8.4 Lubricating oil failure

8.4.1 Main turbines are to have an arrangement whereby fuel is automatically shut off, near the burners, in the event of failure of the lubrication system.

8.5 Indication of temperature

8.5.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

8.6 Automatic and remote controls

8.6.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarm and safety arrangements required by 8.6.2 and Table 2.8.1 as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

8.6.2 The following turbine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine:

(a) Lubricating oil supply.
(b) Oil fuel supply, *see also* 8.6.3.
(c) Exhaust gas.

8.6.3 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by 8.6.2.

8.6.4 A means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station.

Table 2.8.1 Alarms and safeguards

Item	Alarm	Note
Overspeed	High	Automatic shut down
Lubricating oil pressure for turbine and gearing	1st stage low	
	2nd stage low	Automatic shut down
Lubricating oil temperature	High	
Lubricating oil filter differential pressure	High	
Oil fuel supply pressure	Low	
Oil fuel supply temperature	High	
Bearing temperature	High	
Exhaust gas temperature	1st stage high	
	2nd stage high	Automatic shut down
Turbine vibration	1st stage high	
	2nd stage high	Automatic shut down
Rotor axial displacement	High	Automatic shut down, *see* Note 2
Flame and ignition	Failure	Automatic shut down
Automatic starting	Failure	Automatic shut down
Compressor inlet vacuum	1st stage high	
	2nd stage high	Automatic shut down
Control system	Failure	

NOTES
1. Automatic or interlocked means are to be provided for clearing all parts of the main gas turbine of the accumulation of liquid fuel or for purging gaseous fuel, before ignition commences on starting or recommences after failure to start.
2. Except for gas turbines with rolling element bearings.

■ *Section 9*
Requirements for craft which are not required to comply with the HSC Code

9.1 General

9.1.1 The requirements of Sections 1 to 8 apply to craft which are not required to comply with the HSC Code, unless specifically exempted by the contents of this Section.

9.1.2 The requirements of 1.4.1 do not apply to yachts or service craft less than 24 m.

9.2 Information and calculations

9.2.1 Gas turbines for craft with a power output not exceeding 110 kW do not have to comply with 2.1.2(c) and (d) or 2.1.4 to 2.1.7 inclusive and 2.1.9.

9.3 Starting arrangements

9.3.1 Craft with a Service Group notation of G1 or G2 do not have to comply with 6.1.1.

9.4 Piping systems

9.4.1 Soft solder is not to be used for attaching pipe fittings forming part of oil fuel systems.

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LIFE MATTERS

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Section 1
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter, except where otherwise stated are applicable to electric motor, gas turbine and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/impeller(s) for main propulsion purposes, for transmitted powers greater than 220 kW.
(b) Auxiliary machinery which is essential for the safety of the craft or for safety of persons on board where the transmitted powers exceed 110 kW.

NOTE
Alternatively calculations using the methods defined in ISO 6336 – *Calculation of load capacity of spur and helical gears* will be considered.

1.1.3 Gear designs for applications other than those specified in 1.1.2 will be specially considered.

1.1.4 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.5 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.6 For vibration and alignment requirements, *see* Part 13.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Inclination of craft

1.3.1 Main and auxiliary gear units are to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

Section 2
Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in 2.2 to 2.3 are to be submitted.

2.2 Plans

2.2.1 **Gearing:**
(a) Cross sectional views indicating general arrangement.
(b) Detailed plans of elements.

2.2.2 **Shafting and auxiliary systems:**
(a) Mass elastic schematic showing gear unit torsional data.
(b) Arrangements plan indicating bearing positions.
(c) Detailed plans indicating scantlings of shafts, couplings and bolting.
(d) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.
(e) Schematic of the control and electrical system.

2.3 Information

2.3.1 **Gearing:**
(a) Operational power/speed envelope for each pinion.
(b) Number of teeth in each gear.
(c) Reference diameters.
(d) Helix angles at reference diameters.
(e) Normal pitches of teeth at reference diameters.
(f) Tip diameters.
(g) Root diameters.
(h) Face widths and gaps, where applicable.
(j) Pressure angles of teeth (normal or transverse) at reference diameters.
(k) Accuracy grade Q in accordance with ISO 1328 or an equivalent Standard.
(l) Surface texture of tooth flanks and roots.
(m) Minimum backlash.
(n) Centre distance.
(o) Basic rack tooth form.
(p) Protuberance and final machining allowance.
(q) Details of post hobbing processes, if any.
(r) Details of tooth flank corrections, if adopted.
(s) Case depth for surface-hardened teeth.
(t) Shrinkage allowance for shrunk-on rims and hubs.
(u) Type of coupling proposed for oil engine applications.
(v) Details of surface treatment.
(w) Additional measures, not covered by the Rules, taken during manufacture of the gear elements, to improve the load capacity of the gear teeth.

(x) Calculations for short term high power operation, where applicable, *see* Part 9.
(y) Failure mode effects analysis as required by Part 9.
(z) Specifications for carbon-manganese and alloy steel forging materials of pinions, pinion sleeves, wheel rims, gear wheels, couplings, bolting and all transmission shafting, giving chemical composition, heat treatment and mechanical properties.

2.3.2 **Shafting and auxiliary systems:**
(a) Details of clutch units, where fitted.
(b) Details of alarms and control systems, where fitted.
(c) Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures.

Section 3 Materials

3.1 Requirements and specifications

3.1.1 Components for gearboxes are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Manufacturers' certificates for forgings may be accepted where the transmitted power does not exceed 220 kW, *see* Ch 1,3.1.3(b) of the Rules for Materials.

3.1.3 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is also to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

3.1.4 Gear wheel and rim forgings with a specified minimum tensile strength not in excess of 760 N/mm^2 may be made in carbon-manganese steel. Gear wheel or rim forgings where the specified minimum tensile strength is in excess of 760 N/mm^2, and all pinion or pinion sleeve forgings are to be made in a suitable alloy steel.

3.1.5 Forgings for couplings, quill shafts and gear wheel shafts are to comply with the requirements of Chapter 2.

Section 4 Design of gearing

4.1 Symbols

4.1.1 The following symbols apply:

a = centre distance, in mm
b = face width, in mm
NOTE: unless otherwise specified, b is to be taken as the lesser value of b_1 or b_2
In the case of double helical gears $b = 2b_B$ where b_B is the width of one helix
d = reference diameter, in mm
d_a = tip diameter, in mm
d_{an} = virtual tip diameter, in mm
d_b = base diameter, in mm
d_{bn} = virtual base diameter, in mm
d_{en} = virtual diameter to the highest point of single tooth pair contact, in mm
d_f = root diameter, in mm
d_{fn} = virtual root diameter, in mm
d_n = virtual reference diameter, in mm
d_s = shrink diameter, in mm
d_w = pitch circle diameter, in mm
f_{ma} = tooth flank misalignment due to manufacturing errors, in µm
f_{pb} = maximum base pitch deviation of wheel, in µm
f_{Sh} = tooth flank misalignment due to wheel and pinion deflections, in µm
f_{Sho} = intermediary factor for the determination of f_{Sh}
g_α = length of line of action for external gears, in mm:

$$= 0{,}5\sqrt{(d_{a1}{}^2 - d_{b1}{}^2)} + 0{,}5\sqrt{(d_{a2}{}^2 - d_{b2}{}^2)} - a \sin\alpha_{tw}$$

for internal gears:

$$= 0{,}5\sqrt{(d_{a1}{}^2 - d_{b1}{}^2)} - 0{,}5\sqrt{(d_{a2}{}^2 - d_{b2}{}^2)} + a \sin\alpha_{tw}$$

h = total depth of tooth, in mm
h_{ao} = basic rack addendum of tool, in mm
h_F = bending moment arm for root stress, in mm
h_W = sum of actual tooth addenda of pinion and wheel, in mm
m_n = normal module, in mm
n = rev/min of pinion
q = machining allowances, in mm
q_s = notch parameter
q' = intermediary factor for the determination of C_γ

$$u = \text{gear ratio} = \frac{\text{Number of teeth in wheel}}{\text{Number of teeth in pinion}} \geq 1$$

v = linear speed at pitch circle, in m/s
x = addendum modification coefficient
y_α = running in allowance, in µm
y_β = running in allowance, in µm
z = number of teeth

$$z_n = \text{virtual number of teeth} = \frac{z}{\cos^2\beta_o \cos\beta}$$

C_γ = tooth mesh stiffness (mean total mesh stiffness per unit face width), in N/mm µm
F_t = nominal tangential tooth load, in N

$$= \frac{P}{nd}\, 19{,}098 \times 10^6$$

F_β = total tooth alignment deviation (maximum value specified), in μm
$F_{\beta x}$ = actual longitudinal tooth flank deviation before running in, in μm
$F_{\beta y}$ = actual longitudinal tooth flank deviation after running in, in μm
HV = Vickers hardness number
K_A = application factor
$K_{F\alpha}$ = transverse load distribution factor
$K_{F\beta}$ = longitudinal load distribution factor
$K_{H\alpha}$ = transverse load distribution factor
$K_{H\beta}$ = longitudinal load distribution factor
K_v = dynamic factor
$K_{v\alpha}$ = dynamic factor for spur gears
$K_{v\beta}$ = dynamic factor for helical gears
K_γ = load sharing factor
P = transmitted power, in kW
P_r = radial pressure at shrinkage surface, in N/mm^2
P_{ro} = protuberance of tool, in mm
Q = accuracy grade derived from ISO 1328 – *Cylindrical gears – ISO system of accuracy*
R_a = surface roughness – arithmetical mean deviation (C.L.A.) as determined by an instrument having a minimum wavelength cut-off of 0,8 mm and for a sampling length of 2,5 mm, in μm
S_{pr} = residual undercut left by protuberance in mm
$S_{F\,min}$ = minimum factor of safety for bending stress
S_{Fn} = tooth root chord in the critical section, in mm
$S_{H\,min}$ = minimum factor of safety for Hertzian contact stress
Y_D = design factor
Y_F = tooth form factor
$Y_{R\,rel\,T}$ = relative surface finish factor
Y_S = stress concentration factor
Y_{ST} = stress correction factor
Y_x = size factor
Y_β = helix angle factor
$Y_{\delta\,rel\,T}$ = relative notch sensitivity factor
Z_E = material elasticity factor
Z_H = zone factor
Z_R = surface finish factor
Z_V = velocity factor
Z_X = size factor
Z_β = helix angle factor
Z_ε = contact ratio factor
α_{en} = pressure angle at the highest point of single tooth contact, in degrees
α_n = normal pressure angle at reference diameter, in degrees
α_t = transverse pressure angle at reference diameter, in degrees
α_{tw} = transverse pressure angle at pitch circle diameter, in degrees
$\alpha_{F\,en}$ = angle for application of load at the highest point of single tooth contact, in degrees
β = helix angle at reference diameter, in degrees
β_b = helix angle at base diameter, in degrees
γ = intermediary factor for the determination of f_{Sh}
ε_α = transverse contact ratio

$$= \frac{g\alpha \cos\beta}{\pi\, m_n \cos\alpha_t}$$

$\varepsilon_{\alpha n}$ = virtual transverse contact ratio
ε_β = overlap ratio

$$= \frac{b \sin\beta}{\pi\, m_n}$$

ε_γ = total contact ratio
ρ_{ao} = tip radius of tool, in mm
ρ_c = relative radius of curvature at pitch point, in mm

$$= \frac{a \sin\alpha_{tw}\, u}{\cos\beta_b\,(1+u)^2}$$

ρ_F = tooth root fillet radius at the contact of the 30° tangent, in mm
σ_y = yield or 0,2 per cent proof stress, in N/mm^2
σ_B = ultimate tensile strength, in N/mm^2
σ_F = bending stress at tooth root, N/mm^2
$\sigma_{F\,lim}$ = endurance limit for bending stress in N/mm^2
σ_{FP} = allowable bending stress at the tooth root, in N/mm^2
σ_H = Hertzian contact stress at the pitch circle, in N/mm^2
$\sigma_{H\,lim}$ = endurance limit for Hertzian contact stress, in N/mm^2
σ_{HP} = allowable Hertzian contact stress, in N/mm^2

Subscript: $_1$ = pinion
$_2$ = wheel
$_0$ = tool

NOTE
a and *z* are considered positive for both external and internal gearing for the purposes of these calculations.

4.2 Tooth form

4.2.1 The tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25m_n.

4.2.2 All sharp edges left on the tips and ends of pinion and wheel teeth after hobbing and finishing are to be removed.

4.3 Tooth loading factors

4.3.1 For values of application factor, K_A, *see* Table 1.4.1.

Table 1.4.1 Values of K_A

Main and auxiliary gears	K_A
Main propulsion – electric motor or gas turbine, reduction gears	1,15
Main propulsion – diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

4.3.2 Load sharing factor, K_γ. When a gear drives two or more mating gears where the total transmitted load is not evenly distributed between the individual meshes, K_γ is to be taken as 1,15, otherwise K_γ is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

4.3.3 **Dynamic factor, K_v:**

For helical gears with $\varepsilon_\beta \geq 1$:

$$K_v = 1 + Q^2 v\, z_1\, 10^{-5} = K_{VB}$$

For helical gears with $\varepsilon_\beta \leq 1$:

$$K_v = K_{va} - \varepsilon_\beta\, (K_{va} - K_{v\beta})$$

For spur gears:

$$K_v = 1 + 1{,}8\, Q^2 v\, z_1\, 10^{-5} = K_{va}$$

where $\dfrac{v\, z_1}{100} > 14$ for helical gears, and

where $\dfrac{v\, z_1}{100} > 10$ for spur gears, the value of K_v will be specially considered

NOTE

Q is to be taken as the larger value of Q_1 or Q_2.

4.3.4 **Longitudinal load distribution factors, $K_{H\beta}$ and $K_{F\beta}$**:

$$K_{H\beta} = 1 + \frac{b\, F_{\beta y}\, C\gamma}{2F_t\, K_A\, K_\gamma\, K_v}$$

Calculated values of $K_{H\beta} > 2$ are to be reduced by improved accuracy and helix correction as necessary:

where

$F_{\beta y} = F_{\beta x} - y_\beta$ and

$F_{\beta x} = 1{,}33 f_{Sh} + f_{ma}$

$f_{ma} = \dfrac{2}{3}\, F_\beta$ at the design stage, or

$f_{ma} = \dfrac{2}{3}\, F_\beta$ where helix correction has been applied

$f_{Sh} = f_{Sho}\, \dfrac{F_t\, K_A\, K_\gamma\, K_v}{b}$ where

$f_{Sho} = 23\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning and without end relief, or

$= 12\gamma\ 10^{-3}$ µm mm/N for gears without helix correction but with crowning, *see* Note 1

$= 16\gamma\ 10^{-3}$ µm mm/N for gears without helix correction or crowning but with end relief, where

$\gamma = \left(\dfrac{b}{d_1}\right)$ for single helical and spur gears

$= 3\left(\dfrac{b}{2d_1}\right)^2$ for double helical gears

The following minimum values are applicable, these also being the values where helix correction has been applied:

$f_{Sho} = 10 \times 10^{-3}$ µm mm/N for helical gears, or

$= 5 \times 10^{-3}$ µm mm/N for spur gears

For through-hardened steels and surface hardened steels running on through-hardened steels:

$y_\beta = \dfrac{320}{\sigma_{H\,lim}}\, F_{\beta x}$ up to an upper limit value of

$y_\beta = \dfrac{12800}{\sigma_{H\,lim}}$ m, and

For surface hardened steels, when

$y_\beta = 0{,}15 F_{\beta x}$ up to an upper limit value of

$y_\beta = 6$ m

$F_{F\beta} = K_{H\beta}\, n$

where

$$n = \frac{\left(\dfrac{b}{h}\right)^2}{1 + \dfrac{b}{h} + \left(\dfrac{b}{h}\right)^2}$$

NOTES

1. $\dfrac{b}{h}$ is to be taken as the smaller of $\dfrac{b_1}{h_1}$ or $\dfrac{b_2}{h_2}$

2. For double helical gears $\dfrac{b}{2}$ is to be substituted for b in the equation for n.

4.3.5 **Transverse load distribution factors, $K_{H\alpha}$ and $K_{F\alpha}$**

$K_{H\alpha} = K_{F\alpha} \geq 1{,}000$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = \frac{\varepsilon\gamma}{2}\left(0{,}9 + \frac{0{,}4C\gamma\, (f_{pb} - Y_\alpha)\, b}{F_t\, K_A\, K_\gamma\, K_v\, K_{H\beta}}\right)$$

where

$\varepsilon\gamma \leq 2$

$$K_{H\alpha} = 0{,}9 + 0{,}4\sqrt{\frac{2\,(\varepsilon_\gamma - 1)}{\varepsilon_\gamma}}\left(\frac{C_\gamma\, (f_{pb} - y_\alpha)\, b}{F_t\, K_A\, K_\gamma\, K_v\, K_{H\beta}}\right), \text{ but}$$

$K_{H\alpha} \leq \dfrac{\varepsilon_\gamma}{\varepsilon_a\, Z_\varepsilon^{\,2}}$ and

$K_{F\alpha} \leq \dfrac{\varepsilon_\gamma}{0{,}25\varepsilon_\gamma + 0{,}75}$

When tip relief is applied, f_{pb} is to be half of the maximum specified value:

$y_\alpha = \dfrac{160}{\sigma_{H\,lim}}\, f_{pb}$ for through-hardened steels, when

$y_\alpha \leq \dfrac{6400}{\sigma_{H\,lim}}$ µm and

$y_\alpha = 0{,}075 f_{pb}$ for surface hardened steels, when

$y_\alpha \leq 3$ µm

When pinion and wheel are manufactured from different materials:

$$y_\alpha = \frac{y_{\alpha 1} + y_{\alpha 2}}{2}$$

NOTE
Tip relief is to take the form of either tip and root relief on the pinion, or tip relief on pinion and wheel.

4.3.6 **Tooth mesh stiffness, C_γ:**

$$C_\gamma = \frac{0{,}8}{q^1} \cos\beta\,(0{,}75\varepsilon_\alpha + 0{,}25) \quad \text{N/mm}\,\mu\text{m}$$

where

$$q^1 = 0{,}04723 + \frac{0{,}1551}{z_{n1}} + \frac{0{,}25791}{z_{n2}} - 0{,}00635x_1 - \frac{0{,}11654x_1}{z_{n1}} - 0{,}00193x_2 - \frac{0{,}24188x_2}{z_{n2}} + 0{,}00529x_1^2 + 0{,}00182x_2^2$$

For internals gears $z_{n2} = \infty$
Other calculation methods for C_γ will be specially considered.

4.4 Tooth loading for surface stress

4.4.1 The Hertzian contact stress, σ_H, at the pitch circle is not to exceed the allowable Hertzian contact stress, σ_{HP}:

$$\sigma_H = Z_H Z_E Z_\varepsilon Z_\beta \sqrt{\frac{F_t\,(u+1)}{d_1\,bu}\,K_A K_\gamma K_v K_{H\beta} K_{Ha}}$$

and

$$\sigma_{HP} = \frac{\sigma_{H\,lim} Z_R Z_v Z_X}{S_{H\,min}} \text{ for the pinion/wheel combination}$$

where

$$Z_H = \sqrt{\frac{2\cos\beta_b \cos\alpha_{tw}}{\cos^2\alpha_t \sin\alpha_{tw}}}$$

$$Z_E = 189{,}8 \text{ for steel}$$

$$Z_\varepsilon = \sqrt{\frac{4-\varepsilon_\alpha}{3}(1-\varepsilon_\beta) + \frac{\varepsilon_\beta}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta < 1 \text{ and}$$

$$Z_\varepsilon = \sqrt{\frac{1}{\varepsilon_\alpha}} \quad \text{for } \varepsilon_\beta \geq 1$$

$$Z_\beta = \sqrt{\cos\beta}$$

$$Z_R = \left(\frac{1}{R_a}\right)^{0{,}11} \text{ but } Z_R \leq 1{,}14$$

Where R_a is the surface roughness value of the tooth flanks. When pinion and wheel tooth flanks differ then the larger value of R_a is to be taken:

$$Z_v = 0{,}88 + 0{,}23\left(0{,}8 + \frac{32}{v}\right)^{-0{,}5}$$

For values of Z_x, *see* Table 1.4.2
$\sigma_{H\,lim}$, *see* Table 1.4.3
$S_{H\,min}$, *see* Table 1.4.4.

Table 1.4.2 Values of Z_x

Pinion heat treatment		Z_x
Carburised and induction-hardened	$m_n \leq 10$ $10 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}05 - 0{,}005\,m_n$ 0,9
Nitrided	$m_n < 7{,}5$ $7{,}5 < m_n < 30$ $30 \leq m_n$	1,00 $1{,}08 - 0{,}005\,m_n$ 0,75
Through-hardened	All modules	1,00

Table 1.4.3 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$

Heat treatment		
Pinion	Wheel	
Through-hardened	Through-hardened	$0{,}46\sigma_{B2} + 255$
Surface-hardened	Through-hardened	$0{,}42\sigma_{B2} + 415$
Carburised, nitrided or induction-hardened	Soft bath nitrided (tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0{,}88HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

Table 1.4.4 Factors of safety

	$S_{H\,min}$	$S_{F\,min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

4.5 Tooth loading for bending stress

4.5.1 The bending stress at the tooth root, σ_F is not to exceed the allowable tooth root bending stress σ_{FP}:

$$\sigma_F = \frac{F_t}{b\,m_n} Y_F Y_S Y_\beta K_A K_\gamma K_v K_{F\beta} K_{F\alpha} \quad \text{N/mm}^2$$

$$\sigma_{FP} = \frac{\sigma_{F\,lim} Y_{ST} Y_{d\,rel\,T} Y_{R\,rel\,T} Y_x}{S_{F\,min} Y_D} \quad \text{N/mm}^2$$

NOTE
If b_1 and b_2 are not equal the load bearing width of the wider face taken is not to exceed that of the smaller plus $2m_n$.

For values of $S_{F\,min}$, *see* Table 1.4.4
$\sigma_{F\,lim}$, *see* Table 1.4.5
Stress correction factor $Y_{ST} = 2$.

Table 1.4.5 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (Tufftrided)	330
Induction hardened	$0{,}35\,HV + 125$
Gas nitrided	390
Carburised A	450
Carburised B	410

NOTES
1. A is applicable for Cr Ni Mo carburising steels.
2. B is applicable for other carburising steels.

4.5.2 **Tooth form factor, Y_F:**

$$Y_F = \frac{6\,\frac{h_F}{m_n}\cos\alpha_{Fen}}{\left(\frac{S_{Fn}}{m_n}\right)^2\cos\alpha_n}$$

where

h_F, α_{Fen} and S_{Fn} are shown in Fig. 1.4.1.

$$\frac{S_{Fn}}{m_n} = z_n\sin\left(\frac{\pi}{3} - \nu\right) + \sqrt{3}\left(\frac{G}{\cos\nu} - \frac{\rho_{ao}}{m_n}\right)$$

where

$$\nu = \frac{2G}{z_n}\tan\nu - H$$

$$G = \frac{\rho_{ao}}{m_n} - \frac{h_{ao}}{m_n} + x$$

$$H = \frac{2}{z_n}\left(\frac{\pi}{2} - \frac{E}{m_n}\right) - \frac{\pi}{3}$$

$$E = \frac{\pi}{4}m_n - h_{ao}\tan\alpha_n + \frac{S_{pr}}{\cos\alpha_n} - (1 - \sin\alpha_n)\frac{\rho_{ao}}{\cos\alpha_n}$$

E, h_{ao}, α_n, S_{pr} and ρ_{ao} are shown in Fig. 1.4.2.

$$\frac{\rho_F}{m_n} = \frac{\rho_{ao}}{m_n} + \frac{2G^2}{\cos\nu\,(z_n\cos^2\nu - 2G)}$$

$$d_{en} = \frac{2z}{|z|}\left\{\left[\sqrt{\left(\frac{d_n}{2}\right)^2 - \left(\frac{d_{bn}}{2}\right)^2} - \frac{\pi d\cos\beta\cos\alpha_n}{|z|}(\varepsilon_{\alpha n} - 1)\right]^2 + \left(\frac{d_{bn}}{2}\right)^2\right\}^{1/2}$$

where

$$d_{an} = d_n + d_a - d$$

$$d_n = \frac{d}{\cos^2\beta_b}$$

$$d_{bn} = d_n\cos\alpha_n$$

$$\varepsilon_{\alpha n} = \frac{d}{\cos^2\beta_b}$$

$$\gamma_e = \frac{\frac{\zeta\pi}{2} + 2x\tan\alpha_n}{z_n} + \text{inv.}\,\alpha_n - \text{inv.}\,\alpha_{en}$$

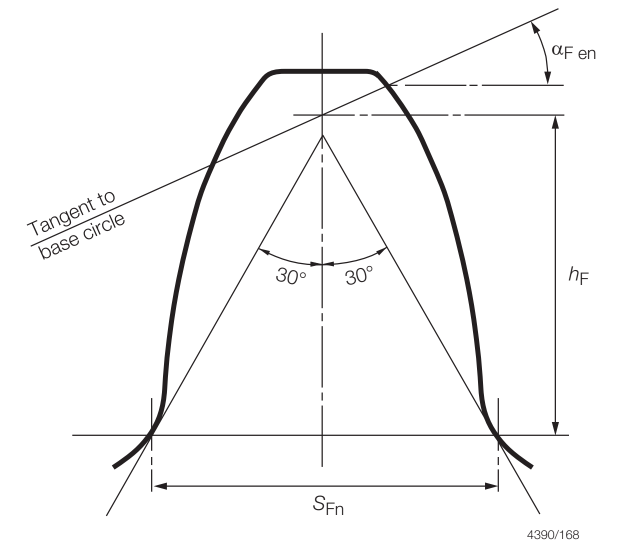
where

$$\alpha_{en} = \text{arc cos}\,\frac{d_{bn}}{d_{en}}$$

$$\frac{h_F}{m_n} = \frac{1}{2}\left[(\cos\gamma_e - \sin\gamma_e\tan\alpha_{F\,en})\frac{d_{en}}{m_n} - z_n\cos\left(\frac{\pi}{3} - \nu\right) - \frac{G}{\cos\nu} + \frac{\rho_{ao}}{m_n}\right]$$

where

$$\alpha_{F\,en} = \alpha_{en} - \gamma_e.$$



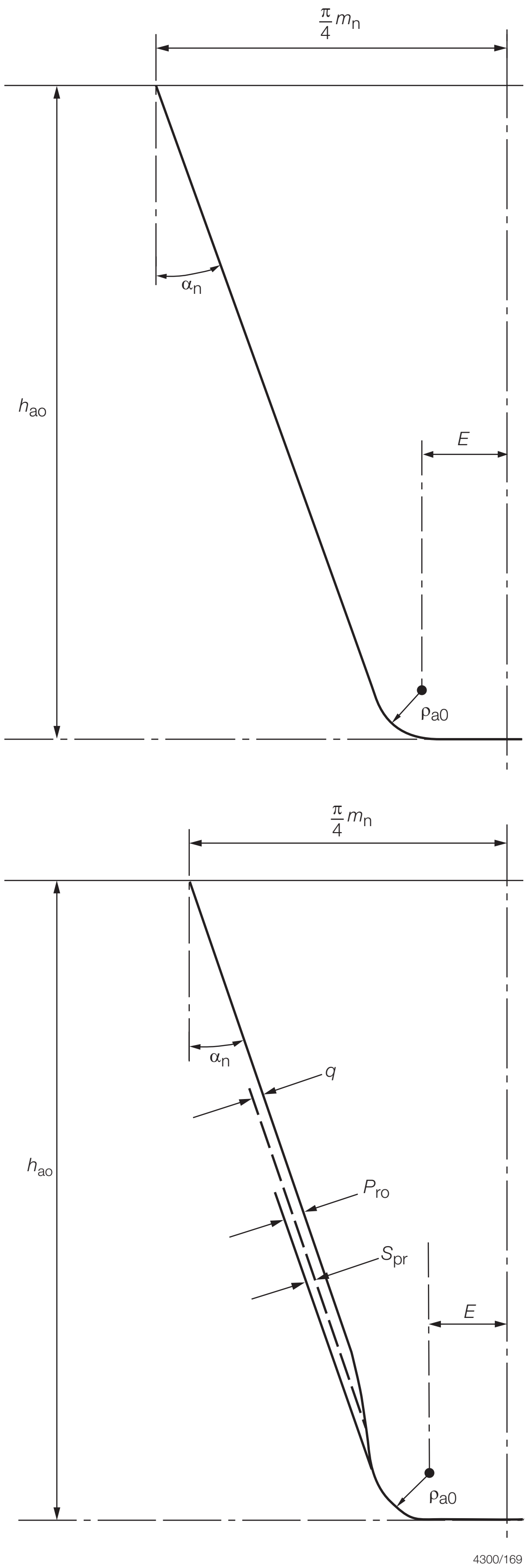
NOTE
For helical gears the normal section is taken with the virtual number of teeth

Fig. 1.4.1 Normal tooth section

4.5.3 For internal tooth forms the form factor is calculated, as an approximation, for a substitute gear rack with the form of the basic rack in the normal section, but having the same tooth depth as the internal gear:

$$\frac{S_{Fn2}}{m_n} = 2\left[\frac{\pi}{4} + \tan\alpha\left(\frac{h_{ao2} - \rho_{ao2}}{m_n}\right) + \left(\frac{\rho_{ao2} - S_{pr}}{m_n}\right) - \frac{\rho_{ao2}}{m_n}\cos\frac{\pi}{6}\right], \text{ and}$$

$$\frac{h_{F2}}{m_n} = \frac{d_{en2} - d_{fn2}}{2m_n} - \left[\frac{\pi}{4} + \left(\frac{h_{ao2}}{m_n} - \frac{d_{en2} - d_{fn2}}{2m_n}\right)\tan\alpha_n\right]\tan\alpha_n - \frac{\rho_{ao2}}{m_n}\left(1 - \sin\frac{\pi}{6}\right)$$



NOTES
1. Dimensions shown in rack profile of tooth
2. $S_{pr} = P_{ro} - q$

Fig. 1.4.2 External tooth forms

where

$\alpha_{F\,en}$ is taken as being equal to α_n

$$\rho_{F2} = \frac{\rho_{ao2}}{2}$$

d_{en2} is calculated as d_{en} for external gears, and

$$d_{fn} = d - d_f - d_n$$

4.5.4 **Stress concentration factor, Y_s**

$$Y_s = (1{,}2 + 0{,}13L)\, q_s^{\left(\frac{1}{1{,}21 + 2.3/L}\right)}$$

where

$$L = \frac{S_{Fn}}{h_F}$$

$$q_s = \frac{S_{Fn}}{2\rho_F}$$

when

$q_s < 1$ the value of Y_s is to be specially considered.

The formula for Y_s is applicable to external gears with $\alpha_n = 20°$ but may be used as an approximation for other pressure angles and internal gears.

4.5.5 **Helix angle factor Y_β**

$$Y_\beta = 1 - \left(\varepsilon_\beta \frac{\beta}{120}\right), \text{ if } \varepsilon_\beta > 1 \text{ let } \varepsilon_\beta = 1$$

but

$$Y_b \geq 1 - 0{,}25\varepsilon_\beta \geq 0{,}75$$

4.5.6 **Relative notch sensitivity factor, $Y_{\delta\,rel\,T}$**

$Y_{\delta\,rel\,T} = 1 + 0{,}036\,(q_s - 2{,}5)\left(1 - \frac{\sigma_y}{1200}\right)$ for through-hardened steels

$= 1 + 0{,}008\,(q_s - 2{,}5)$ for carburised and induction-hardened steels, and

$= 1 + 0{,}04\,(q_s - 2{,}5)$ for nitrided steels.

4.5.7 **Relative surface finish factor, $Y_{R\,rel\,T}$**

$Y_{R\,rel\,T} = 1{,}674 - 0{,}529\,(6R_a + 1)^{0{,}1}$ for through-hardened, carburised and induction hardened steels, and

$= 4{,}299 - 3{,}259\,(6R_a + 1)^{0{,}005}$ for nitrided steels.

4.5.8 **Size factor, Y_x**

$Y_x = 1{,}00$, when $m_n \leq 5$

$= 1{,}03 - 0{,}006m_n$ for through-hardened steels

$= 0{,}85$, when $m_n \geq 30$

$= 1{,}05 - 0{,}01\,m_n$ for surface-hardened steels

$= 0{,}80$, when $m_n \geq 25$.

4.5.9 **Design factor, Y_D**

Y_D = 0,83 for gears treated with a controlled shot peening process

= 1,5 for idler gears

= 1,25 for shrunk on gears, or

$$= 1 + \frac{0{,}2 d_s^2\, d\, P_r\, b}{F_t\, \sigma_{F\,lim}\,(d_f^2 - d_s^2)}\text{, otherwise}$$

= 1,00, or any combination of the above – e.g. Y_D = (0,83 x 1,5) for an idler gear treated with a controlled shot peening process.

4.6 Factors of safety

4.6.1 Factors of safety are shown in Table 1.4.4.

4.7 Design of enclosed gear shafting

4.7.1 The following symbols apply:
P in kW and *R* in rpm, *see* 1.2.1.

L = span between shaft bearing centres, in mm

α_n = normal pressure angle at the gear reference diameter, in degrees

β = helix angle at the gear reference diameter, in degrees

d_w = pitch circle diameter of the gear teeth, in mm

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

NOTE
Numerical value used for σ_u is not to exceed 800 N/mm^2 for gear and thrust shafts and 1100 N/mm^2 for quill shafts.

4.7.2 This sub-Section is applicable to the main and ancillary transmission shafting, enclosed within the gearcase.

4.7.3 The diameter of the enclosed gear shafting adjacent to the pinion or wheel is to be not less than the greater of d_b or d_t, where:

$$d_b = 365 \left(\frac{P\,L}{R\,d_w\,S_b}\right)^{1/3} \left(1 + \left(\frac{\tan\alpha_n}{\cos\beta} + \frac{\tan\beta\, d_w}{L}\right)^2\right)^{1/6}$$

$$d_t = 365 \left(\frac{P}{R\,S_s}\right)^{1/3}$$

where

S_b = 45 + 0,24 (σ_u – 400) and

S_s = 42 + 0,09 (σ_u – 400).

4.7.4 For the purposes of the above it is assumed that the pinion or wheel is mounted symmetrically spaced between bearings.

4.7.5 Outside a length equal to the required diameter at the pinion or wheel, the diameter may be reduced, if applicable, to that required for d_t.

4.7.6 For bevel gear shafts, where a bearing is located adjacent to the gear section, the diameter of the shaft is to be not less than d_t. Where a bearing is not located adjacent to the gear the diameter of the shaft will be specially considered.

4.7.7 The diameter of quill shaft (not axially constrained and subject only to external torsional loading) is to be not less than given by the following formula:

$$\text{Diameter of quill shaft} = 101 \sqrt[3]{\frac{P400}{R\,\sigma_u}} \text{ mm.}$$

4.7.8 Where a shaft, located within the gearcase, is subject to the main propulsion thrust, the diameter at the collars of the shaft transmitting torque, or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than 1,1d_t. For thrust bearings located outside the gearcase, *see* Chapter 2.

4.8 Gear wheels

4.8.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

4.9 External shafting and components

4.9.1 For shafting external to the gearbox and other components ancillaries, *see* Pt 11, Ch 2.

4.10 Clutch actuation

4.10.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

4.11 Gearcases

4.11.1 Gearcases and their supports are to be designed sufficiently stiff such that misalignment at the mesh due to movements of the external foundations and the thermal effects under all conditions of service do not disturb the overall tooth contact.

4.11.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot be readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. Their attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

4.11.3 For gearcases fabricated by fusion welding the carbon content of the steels should generally not exceed 0,23 per cent. Steels with higher carbon content may be approved subject to satisfactory results from weld procedure tests.

4.11.4 Gearcases are to be stress relieved upon completion of all welding.

4.11.5 Gearcases manufactured from material other than steel will be considered upon full details being submitted.

4.12 Backlash

4.12.1 The normal backlash between any pair of gears should not be less than:

$$\frac{a\alpha_n}{90\,000} + 0{,}1 \text{ mm}$$

4.12.2 The normal backlash is not to exceed three times the value calculated in 4.12.1.

4.13 Alignment

4.13.1 Reduction gears with sleeve bearings, for main and auxiliary purposes are to be provided with means for checking the internal alignment of the various elements in the gearcases.

4.13.2 In the case of separately mounted reduction gearing for main propulsion, means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board the craft.

■ *Section 5*
Piping systems for gearing

5.1 General

5.1.1 Piping systems for gearing are to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems should be kept to a minimum. Flexible pipes are to be of an approved type.

5.2 Pumps

5.2.1 Where lubricating oil for the reduction gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with Part 15.

5.3 Filters

5.3.1 Where the lubricating oil for the reduction gearing is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gear set or reducing the supply of filtered oil to the gearing.

■ *Section 6*
Control and monitoring

6.1 General

6.1.1 Control engineering systems are to be in accordance with Part 16.

6.1.2 All main and auxiliary gear units, intended for essential services, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

6.2 Unattended machinery

6.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with the alarms and safety arrangements required by 6.2.2 and Table 1.6.1. The sensors and circuits utilised for the second stage alarm and automatic shut down in Table 1.6.1 are to be independent of those required for the first stage alarm.

Table 1.6.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	
Lubricating oil inlet pressure*	1st Stage Low	
	2nd Stage Low	Automatic shutdown of engine
Lubricating oil inlet temperature*	High	
Thrust bearing temperature*	High	

NOTE
For transmitted powers of 1500 kW or less, only the items marked * are required.

6.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

Section 7
Requirements for craft which are not required to comply with the HSC Code

7.1 Details to be submitted

7.1.1 Failure mode effect analysis is not required for craft which do not require to comply with the HSC Code.

7.1.2 Mass elastic schematic showing gear unit torsional data is only required for gears with an input power greater than 500 kW, *see* 2.2.2 and Part 13.

7.2 Design of gearing

7.2.1 Where they are not intended for passenger carrying duties, the gearing factors of safety for yachts, service craft less than 24 m and ACVs are to satisfy Table 1.7.1.

Table 1.7.1 Factors of safety

	$S_{H\ min}$	$S_{F\ min}$
Main propulsion gears for yachts, etc., single screw	1,25	1,50
Main propulsion gears for yachts, etc., multiple screw	1,20	1,45

7.3 Piping systems

7.3.1 For service craft less than 24 m and for yachts the requirements of 5.2.1 and 5.3.1 do not apply. These craft are to have gearing provided with an efficient lubricating oil pump, a cooler where necessary, and a filter arrangement which can be cleaned.

7.4 Control and monitoring

7.4.1 For service craft less than 24 m the alarms required by 6.2.1 are not required.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives the requirements for the dimensions of transmission shafts, couplings, coupling bolts, keys, keyways, sternbushes and other associated components of main propulsion shafting.

1.1.3 The diameters may require to be modified as a result of alignment considerations and vibration characteristics (*see* Part 13), or the inclusion of stress raisers, other than those contained in this Chapter.

1.1.4 For shafting enclosed within an gearbox, *see* Ch 1,4.7.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see* Part 10.

1.2 Power ratings

1.2.1 In this Chapter, the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, and general requirements defined in Pt 9, Ch 1,1.

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the craft are not endangered, either directly or by damaging the craft or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Particulars to be submitted

2.1 Plans

2.1.1 At least three copies of the following plans are to be submitted:
- Shafting arrangement.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Screwshaft oil gland.
- Screwshaft protection.
- Sternbush and arrangement in housing.
- Couplings.
- Coupling bolts.
- Flexible coupling.
- Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, 'A' bracket and propulsion device, as applicable.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements of this Chapter, fatigue endurance calculations of all components according to Part 9.
- Vibration analysis and alignment analysis as required by Part 13.
- The material specifications, including the minimum specified tensile strength of each shaft and coupling component are to be stated. Where corrosion resistant material not included in Table 2.4.1 is used for unprotected screwshafts the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.

Section 3 Materials

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 Where it is proposed to use alloy steel forgings, particulars of the chemical composition, mechanical properties and heat treatment are to be submitted for approval. For main propulsion shafting, not exposed to sea water, in alloy steels, the specified minimum tensile strength is not to exceed 800 N/mm^2 and for other forgings is not to exceed 1100 N/mm^2.

3.1.3 Unprotected screwshafts and tubeshafts exposed to sea-water are in general to be manufactured, from corrosion resistant ferrous or non-ferrous material, such as those indicated in Table 2.4.1.

3.1.4 In the selection of materials for shafts, keys, locking nuts etc., consideration is to be given to their compatibility with the proposed propeller material.

3.1.5 Where shafts are manufactured from composite material the process is to be approved.

Section 4 Design and construction

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, *d*, of the intermediate shaft is to be not less than:

$$d = F\,k\,\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \quad \text{mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with 4.8 or shrink fit couplings
= 1,10 for shafts with keyways, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125*d*
= 1,10 for shafts with transverse or radial holes where the diameter of the hole does not exceed 0,3*d*
= 1,20 for shafts with longitudinal slots having a length of not more than 1,4*d* and a width of not more than 0,2*d* where *d*, is determined with *k* = 1,0

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings
= 100 for other diesel engine installations

P and *R* are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2.

4.2.2 Beyond a length of 0,2*d* from the end of a keyway, transverse hole or radial hole and 0,3*d* from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with *k* = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of *k* will be specially considered.

4.2.4 The Rule diameter of the intermediate shaft for diesel engines, turbines and electric propelling motors may be reduced by 3,5 per cent for craft classed G1 (Service Group 1), *see* Pt 1, Ch 2,3.5.

4.3 Thrust shafts

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing is to be not less than that required for the intermediate shaft in accordance with 4.2 with a *k* value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be tapered down to that required for the intermediate shaft with a *k* value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea water. Alternatively, the liner may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the craft is slipped, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tube-shafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screw-shaft flange, is to be not less than:

$$d_p = 100k\,\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)} \quad \text{mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland
= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

P and R are as defined in Part 9

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

4.4.4 The diameter, d_p of the screwshaft determined in accordance with 4.4.3 is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by 4.4.4 to the forward end of the stern tube seal is to be determined in accordance with 4.4.3 with a k value of 1,15. The change of diameter from that determined with k = 1,22 or 1,26 to that determined with k = 1,15 should be gradual.

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials having properties as shown in Table 2.4.1 is to be not less than:

$$d_{up} = 128A \sqrt[3]{\frac{P}{R}}$$

where
'A' is taken from Table 2.4.1 and
P and R are as defined in Part 9.

Table 2.4.1 Provisional 'A' Value for use in unprotected screwshaft formula

Material	'A' Value
Stainless steel type 316 (austenitic)	0,71
Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of unprotected screwshafts of materials having properties as shown in Table 2.4.1 forward of the forward stern tube seal is to be determined in accordance with 4.4.7 or 4.4.3, whichever is less.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes having a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o \sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where
d_o = proposed outside diameter, in mm
d_i = diameter of central hole, in mm.

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD} \frac{10^6}{\sigma_u} \frac{P}{R}} \text{ mm}$$

where
n = number of bolts in the coupling
D = pitch circle diameter of bolts, in mm
σ_u = specified minimum tensile strength of bolts, in N/mm^2
P and R are as defined in Part 9.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

4.7.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of 4.7.1. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned in accordance with manufacturer's instructions.

4.7.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pretensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348 \sqrt{\left(\frac{120\ 10^6\ F\ P\ (1 + C)}{R\ D} + Q\right) \frac{1}{n\ \sigma_y}}$$

where d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

P and *R* are defined in Part 9.

F = 2,5 where the flange connection is not accessible from within the craft
= 2,0 where the flange connection is accessible from within the craft

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

4.7.5 Consideration will be given to those arrangements where the bolts are pretensioned to loads other than 70 per cent of the material yield strength.

4.7.6 Where clamp bolts are fitted they are to comply with the requirements of 4.7.4 and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

4.8 Flange connections of couplings

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by 4.7.1, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by 4.2.1.

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 All couplings which transmit torque are to be of approved dimensions.

4.8.5 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.6 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of 4.11.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in Table 2.4.2, where

$$S_c = \frac{24{,}10^6\ P}{R\ d_p\ bhz} \quad \text{N/mm}^2$$

where

P and *R* are defined in Part 9.

d_p = pitch circle diameter of coupling teeth, in mm

b = tooth facewidth, in mm

h = tooth height, in mm

z = number of teeth (per coupling half).

Table 2.4.2 Allowable S_c values

Tooth material surface treatment	Allowable S_c Value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted together with the manufacturer's rating capacity, for the designed operating conditions including short term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/ generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading and overheating is to be given.

4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE

For guidance purposes only $T_{max} = T_{mean}$ (1 + C)

where

C is to be taken from Table 2.4.3

S = 2,0 for assemblies accessible from within the vessel
= 2,5 for assemblies not accessible from within the vessel.

Table 2.4.3 '*C*' values for guidance purposes

Coupling location	C
High Speed Shafting — I.C engine driven	0,3
High Speed Shafting — Electric Motor or Turbine driven	0,1
Low Speed Shafting — main or PTO stage gearing	0,1

4.11.2 The effect of any axial load acting on the assembly is to be considered.

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one-third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155d^3}{\sigma_u\, d_1} \text{ mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24d^3}{\sigma_y\, d_1} \text{ mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_u\, d_1} \text{ mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with 4.2, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2

Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula:

$$t = \frac{D + 230}{32} \text{ mm}$$

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

4.14.3 The thickness of a continuous liner between the bushes is to be not less than 0,75*t*.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk onto the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see* Part 13.

4.16 Sternbushes and sterntube arrangement

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.
(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.
(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.
(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of an approved plastics material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2. The length of the bearing is to be not less than twice its diameter.
(c) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2. The length of the bearing is to be not less than 1,5 times its diameter.
(d) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.
(e) Oil lubricated non-metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

4.16.3 Sternbushes are to be adequately secured in housings.

4.16.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

4.16.5 The shut-off valve or cock controlling the supply of water is to be fitted directly to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.6 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.7 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space, *see also* 5.1.1.

4.16.8 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means. Means for ascertaining the temperature of the oil in the sterntube are also to be provided.

4.16.9 Where an ***IWS** (In-water Survey) notation is to be assigned, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see* Part 13.

■ *Section 5* Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in Table 2.5.1.

Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 Service craft of less than 24 m do not have to comply with 1.3.1 in respect of emergency operation of clutches on single screw installations.

6.2 Details to be submitted

6.2.1 The corrosion fatigue strength of corrosion resistant shaft material need not be submitted if the material is as shown in Table 2.4.1, *see also* 2.2.

6.3 Materials

6.3.1 The proposals to use extruded non-ferrous or composite materials will receive special consideration.

6.3.2 For the survey and testing of shaft material, *see* the Rules for Materials.

6.4 Sternbushes and sterntube arrangement

6.4.1 For service craft less than 24 m, the requirements of 4.16.1 do not apply. Sterntube bearings of approved plastics materials are to be installed so as to ensure a supply of water for lubrication in accordance with the bearing manufacturer's recommendations.

6.4.2 The aftermost propeller shaft bearing in the sterntube is to be secured to prevent rotational and axial movement.

6.4.3 For service craft less than 24 m, the requirements of 4.16.8 do not apply.

6.4.4 The lubrication of propulsion shafting bearings on SES craft less than 24 m will be considered.

6.5 Alarms

6.5.1 The requirements of 5.1.1 do not apply to service craft less than 24 m.

Rules and Regulations for the Classification of Special Service Craft

Volume 7

Part 12

Propulsion Devices

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Lloyd's Register

LIFE MATTERS

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1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of main propulsion components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.3 Highly skewed propellers

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see* Fig. 1.1.1.

1.4 Supercavitating propellers

1.4.1 A supercavitating propeller is defined as one in which the sheet cavity is designed to cover the entire blade width over at least the outer 50 per cent of the blade span.

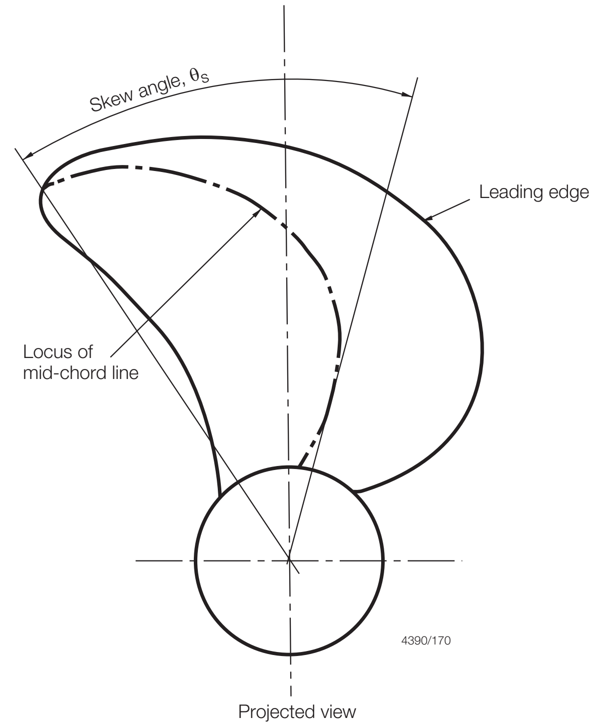

Fig. 1.1.1 Definition of skew angle

Section 2 Plans and particulars

2.1 Particulars to be submitted

2.1.1 At least three copies of the following plans and information are to be submitted.

2.2 Plans

2.2.1 A plan of the propeller, together with the following particulars is to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, *T*, in mm.
(b) Maximum shaft power, *P*, in kW, *see* Part 9.
(c) Estimated craft speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see* (b) and (d)).
(d) Revolutions per minute of the propeller at maximum power, *R*.
(e) Propeller diameter, *D*, in metres.
(f) Pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Pitch at 60 per cent radius, $P_{0,6}$, in metres.
(j) Pitch at 70 per cent radius, $P_{0,7}$, in metres.

(k) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(m) Length of blade section of the expanding cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(n) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(o) Number of blades, N.
(p) Developed area ratio, B.
(q) Material: type and specified minimum tensile strength.
(r) Skew angle, θ_s, in degrees, *see* Fig. 1.1.1.
(s) Connection of propeller to shaft- details of fit, push up and securing.
(t) Keyed connection details.
(u) Details of control/hydraulic system and pressures for CP Propellers actuating mechanisms.
(v) Inertia of propeller assembly, kgm^2.
(w) Total mass of propeller assembly, kg.

2.2.2 For propellers having a skew angle equal or greater than 50° in addition to the particulars detailed in 2.2.1 details are to be submitted of:
(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the ahead mean wake condition and when absorbing full power:
    (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
    (ii) Section pressure distributions calculated by either an advised viscid or viscous procedure.

2.3 Calculations and information

2.3.1 In cases where the craft has been the subject of model wake field tests a copy of the results is to be submitted.

2.3.2 The following information is to be submitted as applicable:
- For controllable pitch propellers plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
- Details of control engineering aspects in accordance with Part 16.
- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation.
- Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
- For cases where the propeller material is not specified in Table 1.3.1, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in sea water in order to assign a value for U.

Section 3
Materials

3.1 Castings for propellers

3.1.1 Castings for propellers and propeller blades are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The chemical composition and mechanical properties of steel castings are given in Ch 4,5 of the Rules for Materials and those of the copper alloys are given in Ch 9,1 of the Rules for Materials.

3.1.2 The specified minimum tensile strength of the castings is to be not less than stated in Table 1.3.1.

Table 1.3.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium – nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41
Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	39
Grade Cu 3 Ni-Aluminium bronze	590	7,6	56
Grade Cu 4 Mn-Aluminium bronze	630	7,5	46

3.1.3 Where propellers of carbon and low alloy steels shown in Table 1.3.1 are provided with an approved method of cathodic protection, special consideration will be given to the value of U.

■ *Section 4* Propeller design

4.1 Minimum blade thickness

4.1.1 For propellers having a skew angle of less than 25° as defined in 1.3.1, the minimum blade thickness, T, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{KCA}{EFULN} + 100\sqrt{\frac{3150MP}{EFRULN}} \text{ mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$, as appropriate

$K = \dfrac{GBD^3R^2}{675}$

G = density, in g/cm^3, *see* Table 1.3.1

U = allowable stress, in N/mm^2, *see* 4.1.2, 4.1.3, 4.1.4 and Table 1.3.1.

$E = \dfrac{\text{actual face modulus}}{0{,}09T^2\,L}$

For aerofoil sections with and without trailing edge washback, E may be taken as 1,0 and 1,25 respectively.

For solid propellers at 25 per cent radius

C = 1,0

$$F = \frac{P_{0,25}}{D} + 0{,}8$$

$$M = 1{,}0 + \frac{3{,}75D}{P_{0,7}} + 2{,}8\frac{P_{0,25}}{D}$$

For controllable pitch propellers at 35 per cent radius

C = 1,4

$$F = \frac{P_{0,35}}{D} + 1{,}6$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 2{,}6\frac{P_{0,35}}{D}$$

For all propellers at 60 per cent radius

C = 1,6

$$F = \frac{P_{0,6}}{D} + 4{,}5$$

$$M = 1{,}35 + \frac{5D}{P_{0,7}} + 1{,}35\frac{P_{0,6}}{D}$$

4.1.2 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of U is to be multiplied by

$$\left(\frac{r}{T}\right)^{0,2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm.

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

4.1.3 The value U may be increased by 10 per cent for twin screw and outboard propellers of triple screw craft.

4.1.4 For propellers having skew angles of 25° or greater, but less than 50°, the mid chord thickness, $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$$T_{sk0,6} = 0{,}54T_{0,6}\sqrt{(1 + 0{,}1\theta_s)} \text{ mm}$$

The mid chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0{,}75T_{root}\sqrt[4]{(1 + 0{,}1\theta_s)} \text{ mm}$$

where

θ_s = proposed skew angle as defined in 1.3.1

$T_{0,6}$ = thickness at 60 per cent radius, calculated by 4.1.1

$T_{sk\ root}$ = thickness at 25 per cent radius or 35 per cent radius, calculated by 4.1.1

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

4.1.5 Results of detailed calculations where carried out, are to be submitted.

4.1.6 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by 5.1.1, a detailed stress analysis for the blades is to be submitted for consideration.

4.2 Interference fit of keyless propellers

4.2.1 The symbols used in 4.2.2 are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$$k_3 = \frac{d_3}{d_1}$$

$$l = \frac{d_i}{d_1}$$

$$p_1 = \frac{2M}{A_1\,\theta_1\,V_1}\left(-1 + \sqrt{1 + V_1\left(\frac{F_1^2}{M^2} + 1\right)}\right)$$

A_1 = contact area fitting at screwshaft, in mm^2

$$B_3 = \frac{1}{E_3}\left(\frac{k_3^2 + 1}{k_3^2 - 1} + \nu_3\right) + \frac{1}{E_1}\left(\frac{1 + l^2}{1 - l^2} - \nu 1\right)$$

C = 0 for turbine installations or electric propulsion

$= \dfrac{\text{vibratory torque at the service speed}}{\text{mean torque at the service speed}}$ for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

$F_1 = \dfrac{2000Q}{d_1}(1 + C)$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in Part 9, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

$V_1 = 0{,}51\left(\dfrac{\mu_1}{\theta_1}\right)^2 - 1$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\dfrac{1}{15}$ on the diameter, i.e. $\theta_1 \le \dfrac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

ν_1 = Poisson's ratio for screwshaft material

ν_3 = Poisson's ratio for propeller material.

4.2.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\delta = \frac{d_1}{\theta_1}\left(p_1 B_3 + (\alpha_3 - \alpha_1)(35 - T_1)\right) \text{ mm}$$

The yield stress or 0,2 per cent proof stress, σ_0, of the propeller material is to be not less than:

$$\sigma_0 = \frac{1{,}4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1(\alpha_3 - \alpha_1)\right)\frac{\sqrt{3k_3^4 + 1}}{k_3^2 - 1} \text{ N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature.

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0{,}002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}(\alpha_3 - \alpha_1)\right) \text{ N.}$$

4.3 Keyed propellers pushed up by an hydraulic nut

4.3.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of frettage a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

4.4 Propeller boss

4.4.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

4.4.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

4.5 Fixed and steering nozzles

4.5.1 The requirements for scantlings for fixed and steering nozzles are given in Pt 3, Ch 3,4.

■ *Section 5* Piping systems

5.1 General

5.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in Part 15.

5.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in Part 15.

5.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Control and monitoring is to comply with the requirements of Pt 16, Ch 1.

6.2 Automatic and remote controls

6.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 6.2.2, 6.2.3 and Table 1.6.1.

6.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

Table 1.6.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*See* Part 16

6.2.3 For controllable pitch propellers, a shaft speed indicator and a pitch indicator which shows the degree of pitch as a measure of the propeller blade or actuator movement are to be provided at each station from which it is possible to control shaft speed or propeller pitch.

■ *Section 7* Requirements for craft which are not required to comply with the HSC Code

7.1 Propellers not exceeding one metre in diameter

7.1.1 The materials and the scantlings need not comply with Sections 1 to 3 inclusive or 4.1 to 4.3 inclusive.

7.1.2 Propellers for service craft less than 24 m and main engine power output not exceeding 500 kW are to be manufactured from materials in accordance with the Rules for Materials at a works recognised for the quality of its casting and machining, and be free from defects.

7.1.3 Certificates of construction are not required.

7.1.4 Specific requirements for the piping systems are given in Part 15.

7.1.5 The alarm and monitoring arrangements, and for controllable pitch propellers, the safety arrangements and standby power sources, will be specially considered, *see also* Part 16.

7.2 Alternative materials and design

7.2.1 Propellers made from materials not listed in the Rules for Materials or of unusual form or design will be specially considered.

■ *Section 1* Scope

1.1 General

1.1.1 For the purposes of these Rules, a waterjet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The waterjet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the waterjet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine waterjet propulsion systems and is to be read in conjunction with the General Requirements for the Design and Construction of Machinery in Chapter 1.

1.1.3 The requirements for a fixed or steerable waterjet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the waterjet unit.

1.1.4 These requirements relate to waterjets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ *Section 2* General requirements

2.1 Waterjet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two waterjet systems is to be provided where these form the sole means of propulsion. For ships where a single waterjet system is the sole means of propulsion, a detailed engineering and safety justification is to be evaluated by LR, *see* 2.3.22. This evaluation process will include a risk analysis, using a recognised technique to verify that sufficient levels of redundancy and monitoring are incorporated in the waterjet unit's essential support systems and operating equipment.

2.1.2 Waterjet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see* Ch 1,3 and within the operational service profiles defined by 2.3.11 and 2.3.12.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in Chapter 1. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Plans to be submitted

2.2.1 Plans, in triplicate, and information as detailed below and in 2.3 and 2.4 are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions.
(b) Steering assembly.
(c) Reversing assembly.
(d) Shaft sealing arrangement assembly.
(e) Longitudinal section of the complete waterjet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and, where applicable, surface finish of the following:

(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc.
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted.
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit waterjet nozzles where fitted.
(d) Components of the retractable buckets where these are used for providing astern thrust.
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication.

(f) Details of any shafting support or guide vanes used in the waterjet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most ‘onerous’ operating condition, *see* 2.3.12, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances, and stress raisers, for the following components:

(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads.
(b) Shaft supports and coupling arrangements.
(c) Inlet guide vanes, if fitted.
(d) Steering components, including the lugs of steerable nozzles where fitted.
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with Pt 11, Ch 2.

2.3.4 Torsional vibration calculations of the complete dynamic system in accordance with the relevant requirements included in Pt 13, Ch 1.

2.3.5 Shaft lateral vibration calculations where required by Pt 13, Ch 3.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the waterjet.

2.3.12 The waterjet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the waterjet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the waterjet system will meet the self-priming criteria, *see* 3.1.6.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength is to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design in accordance with Pt 16, Ch 1.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured is to be defined together with a justification.

2.3.21 Details of the waterjet’s loading reactions together with the positions of application within the hull and is to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The waterjet unit’s rated flow and head.

2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Failure Mode and Effects Analysis report (FMEA), *see* 2.4.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. This is to include any in-water engineering procedures where recommended by the waterjet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Failure Mode and Effects Analysis (FMEA)

2.4.1 An FMEA is to be carried out where a single waterjet system is the ship's sole means of propulsion, *see* 2.2.3. The FMEA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

2.4.2 The FMEA is to be carried out using the format presented in Table 22.2.1 in Chapter 22 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships) or an equivalent format that addresses the same reliability issues. Analyses in accordance with IEC 60812 *Analysis for System Reliability – Procedure for Failure Mode and Effects Analysis*, or the IMO Code of Safety for High Speed Craft, 2000, Annex 4 – *Procedures for Failure Mode and Effects Analysis*, would be acceptable.

2.4.3 The FMEA is to be organised in terms of equipment and function. The effects of item failures at a stated level and at higher levels are to be analysed to determine these effects on the system as a whole. Actions for mitigation of the effects of failure are to be determined, *see* 2.4.1.

2.4.4 The FMEA is to:

(a) identify the equipment or sub-system and mode of operation;
(b) identify potential failure modes and their causes;
(c) evaluate the effects on the system of each failure mode;
(d) identify measures for reducing the risks associated with each failure mode;
(e) identify measures for preventing failure; and
(f) identify trials and testing necessary to prove conclusions.

2.4.5 At sub-system level it is acceptable, for the purposes of these Rules, to consider failure of equipment items and their functions. It is not required that the failure of components within that equipment item be analysed, *see* Ch 22,2.1.5 of the Rules for Ships.

2.4.6 Where a FMEA is used for consideration of systems that depend on software-based functions for control or co-ordination, the analysis is to investigate failure of the functions rather than a specific analysis of the software code itself.

■ *Section 3* Design requirements

3.1 General

3.1.1 The arrangement of waterjet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in Pt 9, Ch 2,8.2.
(d) Astern running conditions for the craft.

3.1.2 The mean loadings are those loadings induced by the waterjet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the waterjet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components are to comply with Pt 11, Ch 2. For calculation purposes the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion-resistant material is not to be less than that given in Pt 11, Ch 2,4.4.7.

3.2.4 The use of composite shafts is permitted, *see* 2.3.16.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slip-page of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, the design of the bolted connection should demonstrate a factor of safety of 1,5 when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, then the requirements of Pt 11, Ch 2,4.12 are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of Ch 1,4.2, as applicable, excluding the requirements for Ice Class. Use of the words 'propeller' and 'screwshaft' are to be taken as meaning 'impeller' and 'impellershaft' respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered, for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided, which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of waterjet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller is to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:

- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see* 3.1.1.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the hub and bolting arrangements.

3.4.6 Where an impeller has welded blades, the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the waterjet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by 3.1.1 or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, then consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the waterjet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of 3.7 are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the FMEA and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure are to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of Pt 14, Ch 1.

3.7.2 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments which may be reacted through the body of the nozzle. In this analysis, the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.3 In addition to the requirements of Pt 14, Ch 1, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined by IMO Resolution MSC.137(76), Standards for Ship Manoeuvrability.

3.7.4 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.5 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis is to be given to essential bolting arrangements in critical locations as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR. These are to include bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

Section 4
Piping systems

4.1 General

4.1.1 The piping systems for a waterjet unit are to comply with the general requirements of Pt 15, Ch 3.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of Pt 15, Ch 3; in addition, steering hydraulic systems are to comply with the applicable requirements of Pt 14, Ch 1.

Section 5
Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with Pt 16, Ch 1.

5.1.2 Steering control for the waterjet is to be provided at the ship's normal conning stations.

5.1.3 For waterjets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device, that controls the angular position and/or the reversing angle, is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.4 Means are to be provided at each control station to stop each waterjet.

5.2 Monitoring and Alarms

5.2.1 In addition to the requirements of Pt 14, Ch 1, alarms and monitoring requirements are indicated in 5.2.2 to 5.2.4 and Table 12.5.1.

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with waterjet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by Pt 16, Ch 1.

Section 6
Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of Pt 16, Ch 2.

6.1.2 Waterjet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

Section 7
Inspection, testing and fitting of waterjets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process and meet the requirements of ISO 1940 or an alternative standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required unless otherwise agreed by the Manufacturer and LR.

Table 12.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	–
Hydraulic oil supply tank level	Low	–
Hydraulic oil temperature	High	Where an oil cooler is fitted
Lubricating oil temperature	High	
Lubricating oil pressure	Low	In forced lubrication systems
Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet > 4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversng system
Control system power supply	Failure	

7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:

(a) The balancing of the impeller or the blades.
(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system: for austenitic stainless steels, *see* Ch 4,8, and for aluminium alloys, *see* Ch 8,3, of the Rules for Materials.
(c) The quality of the fit of the impeller boss on the shaft taper.
(d) The fitting of the impeller to the shaft and its subsequent functional testing.
(e) The finished surfaces of the impeller boss, hub, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the FMEA and where indicated by the Manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of waterjet systems

7.2.1 The completed waterjet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the waterjet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the Manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with Pt 15, Ch 1.

7.3 Sea trial requirements

7.3.1 The following requirements are to be complied with:

- Pt 9, Ch 2,8.2 for sea trials.
- Pt 14, Ch 1,4.4 for steering trials.

In addition, the general design capability specified in 3.1.1 is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the waterjet is to be the subject of harbour and then sea trials. Demonstration of the requirements of Pt 16, Ch 1 is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions, the relationship between ship speed and impeller rotational speed is to be verified against the waterjet's design basis.

7.3.4 Any trials and testing identified from the FMEA report, *see* 2.4, are to be carried out.

■ *Section 8* Installation, maintenance and replacement

8.1 General

8.1.1 All waterjet system propulsion units are to be provided with a copy of the Manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See* 2.3.24.

8.1.2 The manual required by 8.1.1 is to be placed on board and is to contain the following information:

(a) Description of the waterjet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of the system on board ship with details of any required specialised equipment.
(d) Instructions for commissioning at initial installation and following maintenance.
(e) Maintenance and service instructions to include inspection/renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment where applicable.
(f) Actions required in the event of fault/failure conditions being detected.
(g) Precautions to be taken by personnel working during installation and maintenance.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in Part 9.

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units are to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of craft

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in Part 9.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the following plans are to be submitted.

2.1.2 **Fixed/Azimuth propulsion thrusters**

(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.

(b) Detailed and dimensional plans of the individual torque transmitting components.

(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.1.3 **Tunnel thrusters.**
Structural assembly plan including connections to tunnel.

2.2 Calculations and specifications

2.2.1 At least three copies of the following information are to be submitted.

2.2.2 **Fixed/Azimuth propulsion thrusters**

(a) Thruster prime mover type and operational power/speed envelope.

(b) Rating and type of motor for the azimuthing mechanism (e.g. type – hydraulic or electric).

(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.

(d) Bearing specifications.

(e) Details of control engineering aspects in accordance with Pt 16, Ch 1.

(f) Calculations indicating suitability of components for short term high power operation, where applicable. *See* Part 9.

(g) Where carried out in accordance with Part 9, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.2.3 **Tunnel thrusters**. Specification for materials of gears, shafts, couplings and propeller, stock and struts.

■ *Section 3* Materials

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

Section 4
Design and construction

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with Pt 3, Ch 3.

4.1.3 In addition to the requirements of this Section reference is to be made to:

(a) Main transmission gearing (Pt 11, Ch 1).
(b) Main transmission shafting (Pt 11, Ch 2).
(c) Propeller (Chapter 1).
(d) Torsional vibration (Pt 13, Ch 1).
(e) Lateral vibration for shafting systems which include cardan shafts (Pt 13, Ch 3).

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with:

(a) The azimuthing mechanism is to be capable of a maximum rotational speed of not less than 1,5 rev/min.
(b) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard.
The design is to consider both static (<10^3 cycles) and dynamic loading conditions.
(c) Under dynamic operating conditions, the gear is to be considered for
  (i) design maximum dynamic duty steering torque,
  (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.
(d) Under a static duty (<10^3 load cycles) steering torque, which should be not less than M_T, as defined in 4.3.1.
(e) The following minimum factor of safety values are to be achieved:
Surface Stress S_{Hmin} = 1,0.
Bending Stress S_{Fmin} = 1,5.
(f) For hydraulic pressure retaining parts and load bearing components, *see also* Part 14.

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in Table 1.4.1 in Pt 14, Ch 1 is to be determined as follows:

$$d_{SU} = 26{,}03 \sqrt[3]{(V + 3)^2 A_N X_{PF}} \quad \text{mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation
A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle
X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from Table 3.2.6 in Pt 3, Ch 3.

The corresponding maximum turning moment, M_T, is to be determined as follows:

$$M_T = 11{,}1 \times d_{SU}^3 \quad \text{Nmm}$$

4.3.2 In addition to the requirements of Part 3 the scantlings of the nozzle stock or steering tube are to be such that the section modulus Z against transverse bending at any section x–x is not less than:

$$Z = 1{,}73 \sqrt{(V + 3)^4 A_N^2 X_{PF}^2 + \frac{a^2}{4} T_M^2 10^4} \quad \text{cm}^3$$

where

a = dimension, in metres, as shown in Fig. 3.4.1
T_M = maximum thrust of the thruster unit, in tonnes.

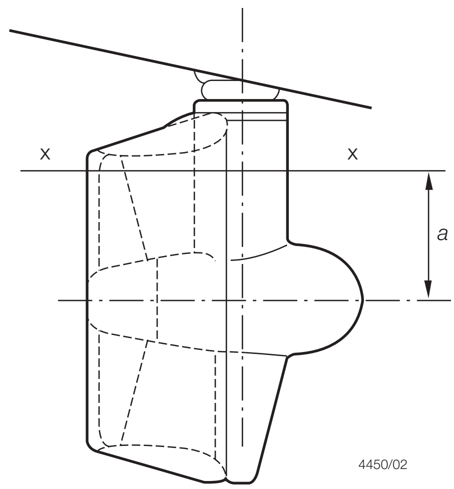

Fig. 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered craft, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

Section 5
Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in Pt 15, Ch 1.

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in Pt 15, Ch 3.

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:
(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system,
(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

■ *Section 6* Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section the control engineering systems are to be in accordance with Pt 16, Ch 1.

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 3.6.1.

6.2.2 An indication of the angular position of the azimuth thruster(s) and the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

6.2.3 All alarms associated with thruster unit faults are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by Part 16.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	—	Indicators, *see* 6.2.2
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

■ *Section 7* Electrical systems

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of Part 16.

7.2 Emergency power for steering systems and drives

7.2.1 For high speed craft, in the event of total power failure, either:
(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as the auxiliary/emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators), or
(b) means are to be provided to bring the craft to a safe condition.

7.3 Circuits

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 8*
Requirements for craft which are not required to comply with the HSC Code

8.1 Design and installation

8.1.1 Tunnel thrusters on service craft less than 24 m and yachts which are not essential for steering and manoeuvring do not have to comply with the design requirements of this Chapter.

8.1.2 The installation of such thrusters is to be such as to maintain the structural and watertight integrity of the craft.

8.2 Control and monitoring

8.2.1 Alarms and monitoring requirements of Table 3.6.1 are not required for service craft of less than 24 m.

Rules and Regulations for the Classification of Special Service Craft

Volume 7

Part 13

Shaft Vibration and Alignment

July 2012

LIFE MATTERS

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Section 1 General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for essential auxiliary services including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

Section 2 Details to be submitted

2.1 Particulars to be submitted

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, combinator characteristics for installations equipped with controllable pitch propellers.

2.1.4 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.5 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer's estimates of mass moment of inertia for the rotating parts.

2.1.6 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders' harmonic torque data. (On request, Lloyd's Register (hereinafter referred to as 'LR') can provide a table of generalised harmonic torque components for use where appropriate.) The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers' data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

■ *Section 3* **Design**

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

- d = minimum diameter of shaft considered, in mm
- r = ratio N/N_s or N_c/N_s whichever is applicable
- N = engine speed, in rev/min
- N_c = critical speed, in rev/min
- N_s = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min
- Q_s = rated full load mean torque
- τ_c = maximum value of the vibration stress for continuous running at or below the maximum speed, in N/mm^2
- τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2
- σ_u = specified minimum tensile strength of the shaft material, in N/mm^2
- C_k = a factor for different shaft design features, *see* Table 1.3.1
- C_d = a size factor defined as $0{,}35 + 0{,}93d^{-0{,}2}$
- k = the factor used in determining minimum shaft diameter, defined in Pt 11, Ch 2,4.2.1 and 4.4.3.

Table 1.3.1 C_k factors

For intermediate shafts with			For thrust shafts external to engines		For propeller shafts
Integral coupling flanges	Shrink fit couplings	Keyways	On both sides of thrust collar	In way of axial bearing where a roller bearing is used as a thrust bearing	For which k = 1,22 and = 1,26
1,0	1,0	0,60	0,85	0,85	0,55

NOTE
The determination of C_k – factors for shafts other than shown in this Table is at the discretion of LR.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum section between the forward end of the propeller boss and the forward stern gland.

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d (3 - 2r^2) \text{ for } r < 0{,}9 \quad \text{N/mm}^2$$

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d \, 1{,}38 \text{ for } 0{,}9 \le r \le 1{,}05 \quad \text{N/mm}^2$$

$$\tau_t = \pm 1{,}7\tau_c \frac{1}{\sqrt{C_k}} \text{ for } r \le 0{,}8$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of Pt 11, Ch 2. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of intermediate shafts and 600 N/mm^2 in the case of thrust and propeller shafts.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of $0{,}95N_s$ and $1{,}05N_s$ the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm (21 - 0{,}014d) \text{ N/mm}^2.$$

3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$\tau_t = 5{,}5\tau_c$.

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to $\pm 2{,}0Q_s$ in general, or to $\pm 2{,}5Q_s$ for close-coupled revolving field alternating current generators, over the speed range from $0{,}95N_s$ to $1{,}05N_s$. Below $0{,}95N_s$ the amplitudes are to be limited to $\pm 6{,}0Q_s$. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from $0{,}95N_s$ to $1{,}05N_s$ flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in 2.2.3.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of 3.3.1, 3.3.2 and 3.3.3 are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers**. The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between $0{,}85N_s$ and $1{,}05N_s$ are to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings**:

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.

(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances power and/or speed restriction may be required. Where machinery is non-essential, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing**:

(a) The torsional vibration characteristics are to comply with the requirements of 2.2. The vibratory torque should not exceed one-third of the full transmission torque throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given the acceptance of additional vibratory loading on the gears.

(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed where the stresses exceed the limiting values, τ_c, for continuous running. Similar restrictions will be imposed, or other protective measures required to be taken, where vibratory torques or amplitudes are considered to be excessive for particular machinery items.

3.6.2 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at $r = 0{,}8$ the stress due to the upper flank does not exceed τ_c.

3.6.3 Where shafting stresses due to a torsional critical response exceed the limiting values, τ_c, for continuous running, the speed restriction will be from:

$$= \frac{16}{18 - r} N_c \text{ to } \frac{18 - r}{16} N_c \text{ inclusive.}$$

3.6.4 Where calculated vibration stresses due to criticals below $0{,}8N_s$ marginally exceed τ_c or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.5 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_c, having regard to tachometer accuracy.

3.6.6 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.7 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.8 For excessive vibratory torque, stress or amplitude in other components, based on 3.6.1 to 3.6.3, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.9 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

3.6.10 There are to be no restricted speed ranges imposed above a speed ratio of $r \geq 0,8$ under normal operating conditions.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

■ *Section 5* Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.

(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

■ *Section 3* Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l, in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg

= $0{,}785\,(D^2 - d^2)\,G\,l$

M = dry mass of propeller, in kg

$A = \dfrac{m}{M}$

$M_e = M\,(A + 2)$

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min.

3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in 2.2.1(b) the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_c = \frac{0{,}98}{n} \left(\frac{ab}{a + b} \right)^{1/2} \text{ rev/min}$$

where

$$a = \frac{E}{G\, l^2} (66{,}2 + 97{,}5A - 8{,}88A^2)^2 \quad \text{c/min}^2$$

$$b = 91{,}2 \frac{k}{M_e} \quad \text{c/min}^2.$$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4*
Measurements

4.1 General requirements

4.1.1 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

■ *Section 5*
Requirements for craft which are not required to comply with the HSC Code

5.1 General requirements

5.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output or auxiliary engines not exceeding 110 kW output for essential services:
(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of Parts 9, 10, 11 and 12.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

- Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in Part 9.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

■ *Section 2* Details to be submitted

2.1 Particulars to be submitted

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in 2.1.1, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

■ *Section 3* Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 4* Requirements for craft which are not required to comply with the HSC Code

4.1 General requirements

4.1.1 The requirements of this Chapter do not apply to the following types of vessel having main engines not exceeding 500 kW power output unless the spacing of bearings on the propulsion shafting exceeds 30 diameters or cardan shafts are used in the propulsion shafting system:

(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

Section

Section 1
Shaft alignment

1.1 General

1.1.1 The Builder is to carry out shaft alignment calculations for all installations and to prepare alignment procedures detailing the proposed alignment method and the alignment checks.

1.2 Particulars to be submitted for approval – Shaft alignment calculations

1.2.1 Shaft alignment calculations are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') for approval for the following shafting systems:

(a) All geared installations where the screwshaft has a diameter of 300 mm or greater in way of the aftmost bearing.

(b) All direct drive installations which incorporate three or fewer bearings supporting the intermediate and screwshaft aft of the prime mover.

(c) Where prime movers or shaftline bearings are installed on resilient mountings.

1.2.2 The shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;

(b) buoyancy effect of the propeller immersion due to the craft's operating draughts;

(c) effect of predicted hull deformations over the range of the craft's operating draughts, where known;

(d) gear forces, where appropriate;

(e) for multi-engined installations, possible contributions in the mode of operation;

(f) propeller offset thrust effects, where applicable;

(g) bearing loading in the horizontal plane, where appropriate; and

(h) bearing weardown, where applicable, and its effect on the bearing loads.

1.2.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;

(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;

(c) details of propeller offset thrust effects, where employed in calculation;

(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;

(e) manufacturer's specified limits for bending moment and shear force at the shaft couplings of the gearbox/prime movers;

(f) estimated bearing weardown rates for water or grease-lubricated sterntube bearings;

(g) origin of findings where the effect of hull deformation has been considered, *viz*. whether finite element calculations or measured results from sister or similar craft have been used;

(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and

(j) manufacturer's allowable bearing loads.

1.3 Particulars to be submitted for review – Shaft alignment procedure

1.3.1 A shaft alignment procedure is to be submitted for all main propulsion installations detailing, as a minimum, the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the craft's operating profile, for the machinery in cold and hot, static and dynamic conditions;

(b) maximum permissible loads for the proposed bearing designs;

(c) design bearing offsets from the straight line;

(d) design gaps and sags;

(e) location and loads for the temporary shaft supports;

(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;

(g) details of slope-bore of the aftermost sterntube bearing, where applied;

(h) expected shear forces and bending moments at the forward end flange of the shafting system connecting to the gear output shaft or, for direct-drive installations, to the prime mover output flange;

(j) proposed bearing load measurement technique and its estimated accuracy;

(k) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;

(l) proposed shaft alignment acceptance criteria, including the tolerances; and

(m) flexible coupling alignment criteria.

1.4 Design and installation criteria

1.4.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of craft loading and machinery operation, bearing load distribution satisfying the requirements of 1.4.2.

1.4.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the craft's operating conditions.

(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3×10^{-4} rad.

(c) Sterntube bearing loads are to satisfy the requirements of Pt 11, Ch 2,4.16.2.

(d) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowable maximum load, for plain journal bearings, based on the bearing projected area.
(e) Main gear wheel bearing loads are to be within the gear-box manufacturer's specified limits.
(f) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions throughout the shafting system.
(g) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

1.5 Measurements

1.5.1 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the optimised shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

1.6 Flexible couplings

1.6.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see* Section 2.

■ *Section 2*
Requirements for craft which are not required to comply with the HSC Code

2.1 General requirements

2.1.1 The requirements of Section 1 do not apply to the following types of vessel where the main engine does not exceed 500 kW power output:
(a) Service craft of less than 24 m.
(b) Yachts.
(c) ACVs.

2.1.2 The engines, shafting, sterntubes and propeller brackets are to be carefully fitted and well secured to the hull of the craft so that satisfactory alignment of the shafting will be maintained in service.

2.1.3 The alignment of the sterntube and propeller brackets is to be demonstrated before launching and the shafting and engine alignment verified when afloat.

Rules and Regulations for the Classification of Special Service Craft

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Part 14

Steering Systems

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LIFE MATTERS

Chapter Contents

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Section

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery in Part 9.

1.1.2 The requirements of this Chapter apply to the design and construction of steering systems.

(a) A steering system includes:
- all steering devices;
- all mechanical, electrical, and hydraulic linkages;
- all power devices, including manual devices;
- all controls and all actuating systems.

(b) Steering may be achieved by means of:
- air or water rudders;
- foils, flaps, steerable propellers or jets;
- yaw control ports or transverse thrusters;
- differential propulsive thrust;
- variable geometry of the craft or its lift system components; or
- by a combination of these devices.

1.2 Provision of steering gear

1.2.1 Craft are to be provided with a means for steering which is to be of adequate strength and suitable design to enable the craft's heading and direction of travel to be effectively controlled at all designed operating conditions.

1.2.2 Craft are to be provided with a main steering system and an independent auxiliary steering unit. The main and the auxiliary steering units are to be so arranged that the failure of one of them will not render the other one inoperative or unable to bring the craft to a safe situation.

1.2.3 An auxiliary steering system is not a requirement provided the craft is fitted with two independent and identical steering systems, one of which is capable of steering the craft when the second system becomes inoperative.

1.3 Definitions

1.3.1 **Main steering system** means the machinery, the actuator(s), the power units, if any, ancillary equipment, and the means of applying the steering torque, if applicable, necessary for the purpose of steering the craft under design conditions.

1.3.2 **Auxiliary steering system** means the equipment other than any part of the main steering unit necessary to steer the craft in the event of failure of the main steering system.

1.3.3 **Steering power system** means:

(a) In the case of electric steering system, an electric motor and its associated electrical parts.

(b) In the case of electrohydraulic steering system, an electric motor and its associated electrical parts and connected pump.

(c) In the case of other hydraulic steering system units, a driving engine and connected pump.

1.3.4 **Steering control system** means the equipment by which orders are transmitted from the control station to the steering power units. Steering control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.3.5 **Maximum working pressure** means the expected pressure in the system when the steering unit is operated under the most onerous design condition.

■ *Section 2* Particulars to be submitted

2.1 Submission of information

2.1.1 At least three copies of the plans and information as detailed in 2.2 and 2.3 are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings, and scantlings.

2.2.2 Schematic of the hydraulic systems, together with pipe material, relief valve and working pressures.

2.2.3 Details of control engineering aspects in accordance with Pt 16, Ch 1.

2.3 Calculations and information

2.3.1 The manoeuvring characteristics for which the craft has been designed.

2.3.2 Material specifications.

Section 3
Materials

3.1 General

3.1.1 All components are to be in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 All steering unit components transmitting mechanical forces are to be of steel or other approved ductile material. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for low pressure valve bodies and mechanical parts with low stress levels.

3.1.3 Consideration will be given to the acceptance of non-ferrous materials as applicable.

Section 4
Design and performance

4.1 General

4.1.1 Power-operated steering units are to be provided with positive arrangements, such as limit switches, for stopping the unit before the mechanical stops are reached. These arrangements are to be synchronised with the unit itself and not with the steering unit control mechanism.

4.1.2 The steering unit is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

4.1.3 All welded joints within the pressure boundary of an actuator or connecting parts transmitting mechanical loads are to be of full penetration type or of equivalent strength.

4.1.4 Steering devices involving variable geometry of the craft or its lift system components are to be so constructed that any failure of the drive linkage or actuating system will not significantly hazard the craft.

4.2 Actuating systems

4.2.1 Actuators are to be designed in accordance with the relevant requirements of Part 15 for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

4.2.2 Accumulators, if fitted, are to comply with the relevant requirements of Part 15.

4.2.3 The design pressure for calculations to determine the scantlings of piping and other steering components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

4.2.4 The permissible primary general membrane stress is not to exceed the lower of the following values:

$$\frac{\sigma_B}{A} \text{ or } \frac{\sigma_y}{B}$$

where

σ_B = specified minimum tensile strength of material at ambient temperature

σ_y = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature.

A and *B* are given by the following Table:

	Wrought steel	Cast steel	Nodular cast iron
A	3,5	4	5
B	1,7	2	3

4.2.5 Oil seals between non-moving parts, forming part of the external pressure boundary, should be of the metal upon metal type or of an equivalent type.

4.2.6 Hydraulic power operated steering units are to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid taking into consideration the type and design of the hydraulic system;

(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir. The storage tank is to be provided with a contents gauge and be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering unit compartment, if applicable.

4.3 Rudder systems

4.3.1 For the requirements of rudder and rudder stock, *see* Pt 3, Ch 3.

4.3.2 Tillers and quadrants are to comply with the requirements of Table 1.4.1.

4.3.3 On double rudder installations, where the two tillers are connected by mechanical means (tie-bar), the strength and stability of the tie-bar is to be assessed using the maximum steering torque applied to the stock.

4.3.4 Where higher tensile steel bolts are used on bolted tillers and quadrants, the yield and ultimate tensile stresses of the bolt material are to be stated on plans submitted for approval, together with full details of the methods to be adopted to obtain the required setting-up stress. Where proprietary nuts or systems are used, the manufacturer's instructions for assembly are to be adhered to.

Table 1.4.1 Connection of tiller to stock

(1) Dry fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit – tiller to stock for M_T (*see* Notes)	(a) For keyed connection, factor of safety against slippage = 1,1 (b) For keyless connection, factor of safety against slippage = 2,2 (c) Coefficient of friction = 0,12 (d) Grip stress not to be less than 20 N/mm^2
(3) Bolted tiller and quadrant (*see* Symbols and Notes)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim: For 4 connecting bolts: $t_s = 0{,}0014 d_{SU}$ mm For 6 connecting bolts: $t_s = 0{,}0012 d_{SU}$ mm Key to be fitted Diameter of bolts, $\delta_T = \dfrac{0{,}60 d_{SU}}{\sqrt{n_T}}$ mm Distance from centre of stock to centre of bolts should generally be equal to $d_{SU}\left(1{,}0 + \dfrac{0{,}30}{\sqrt{n_T}}\right)$ mm Thickness of flange on each half of the bolted tiller $\dfrac{0{,}66 d_{SU}}{\sqrt{n_T}}$ mm
(4) Key (*see* Symbols and Notes)	Effective sectional area in shear ≥ $0{,}25 d_{SU}{}^2$ mm^2 Key thickness ≥ $0{,}17 d_{SU}$ mm Keyway is to extend over full depth of tiller and is to have a rounded end. Corners are to be provided with suitable radii to avoid high stress at the keyway root.
(5) Section modulus – tiller arm (at any point within its length about vertical axis) (*see* Symbols and Notes)	To be not less than the greater of: (a) $Z_{TA} = \dfrac{0{,}15 d_{SU}{}^3 (b_T - b_s)}{1000 b_T}$ cm^3 (b) $Z_{TA} = \dfrac{0{,}06 d_{SU}{}^3 (b_T - 0{,}9 d_{SU})}{1000 b_T}$ cm^3 If more than one arm is fitted, combined modulus is not to be less than the greater of (a) or (b). For solid tillers, the breadth to depth ratio is not to exceed 2.
(6) Boss (*see* Symbols and Notes)	Depth of boss ≥ d_{SU} Thickness of boss in way of tiller ≥ $0{,}4 d_{SU}$

Symbols

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm
NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the rudder stock, in mm

n_T = number of bolts in coupling, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

d_{SU} = *see* Pt 3, Ch 3

δ_T = diameter of bolts securing bolted tillers and quadrants, in mm

σ_o = minimum yield stress or 0,5 per cent proof stress of the tiller bolt material, in N/mm^2

NOTES

1. If d_{SU} > 400 mm, higher tensile steel bolts are to be used for bolted tillers. A predetermined setting-up load equivalent to a stress of approximately $0{,}7\sigma_o$ should be applied to each bolt assembly. A lower stress may be accepted provided that two keys, complying with item (4) are fitted.
2. Where M_T, the maximum turning moment applied to the stock, is to be taken as the greater of the following:
   (a) $11{,}1 d_{SU}{}^3$ Nmm where d_{SU} is to be determined from Table 3.2.7 in Pt 3, Ch 3 with σ_o taken as 235 N/mm^2 and N = 0.
   (b) The torque generated by the steering gear at the maximum working pressure, *see* 1.3.5.

4.3.5 All steering components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

4.3.6 In bow rudders having a vertical locking pin operated from the deck above, positive means are to be provided to ensure that the pin can be lowered only when the rudder is exactly central. In addition, an indicator is to be fitted at the deck to show when the rudder is exactly central.

4.4 Performance

4.4.1 The main steering system is to be:

(a) Of adequate strength and capable of steering the craft at all speeds and conditions for which the craft is designed and this shall be demonstrated during trials;
(b) operated by power where necessary to meet the requirements of (a) and in any case when the Rules require a rudder stock over 120 mm diameter in way of the tiller; and
(c) so designed that it will not be damaged at maximum astern speed.

4.4.2 The auxiliary steering system is to be:

(a) Of adequate strength and capable of steering the craft at navigable speed and of being brought speedily into action in an emergency.
(b) Operated by power where necessary to meet the requirements of (a) and in any case when the Rules, require a rudder stock over 230 mm diameter in way of the tiller.
(c) Where manual operated steering units are proposed, these are acceptable when the operation does not require an effort exceeding 160N under normal conditions.

4.4.3 Main and auxiliary steering power units are to be:

(a) Arranged to re-start automatically when power is restored after power failure.
(b) Capable of being brought into operation from a position at the control station. In the event of a power failure to any one of the steering power units, an audible and visual alarm is to be given on the control station.
(c) Arranged so that transfer between units can be readily effected.

4.4.4 For high speed craft, in the event of total power failure, either:

(a) emergency power for steering systems/drives is to be restored automatically within five seconds. To achieve this an interim fast acting system may be required to come into operation until such time as auxiliary/ emergency power source comes on line. (Note: starting arrangements are to comply with the requirements relating to starting arrangements of emergency generators); or
(b) means are to be provided to bring the craft to a safe condition.

4.4.5 Where the steering unit is so interconnected that more than one power system, or control system, can be simultaneously operated, the design is to be such that hydraulic locking caused by a single failure cannot occur.

4.4.6 Steering systems, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

■ *Section 5* Piping systems

5.1 Components

5.1.1 Piping, joints, valves, flanges and other fittings are to comply within the requirements of Pt 15, Ch 1 for Class 1 piping system components. The design pressure is to be in accordance with 4.2.3.

5.2 Valve and relief valve arrangements

5.2.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.2.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.2.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.2.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by 5.2.3 are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) The minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them).
Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.3 Flexible hoses

5.3.1 Flexible hoses are to be of approved type, *see* Pt 15, Ch 1,13.

Section 6
Control, monitoring and electrical equipment

6.1 Control

6.1.1 All steering systems are to be be operated from the craft's control station.

6.1.2 If steering systems can also be operated from other positions, then two-way communication is to be arranged between the control station and these other positions.

6.1.3 Steering control is to be provided:
(a) For the main steering unit, both at the control station and in the steering unit compartment, where applicable;
(b) Where the main steering unit is arranged by two independent control systems, both operable from the control station. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.
(c) For the auxiliary steering unit, in the steering unit compartment and, if power operated, it is also to be operable from the control station and is to be independent of the control system for the main steering system.

6.1.4 Electrical control systems are to be independent and separated as far as is practicable throughout their length.

6.1.5 Any main and auxiliary steering unit control system operable from the control station is to comply with the following:
(a) Means are to be provided in the steering unit compartment, if applicable, for disconnecting any control system operable at the control station from the steering unit it serves;
(b) The system is to be capable of being brought into operation from a position on the control station.

6.1.6 Appropriate operating instructions with a block diagram showing the change-over procedures for steering unit control systems and steering unit actuating systems are to be permanently displayed at the control station and in the steering unit compartment, if applicable.

6.1.7 Where the system failure alarms for hydraulic lock, *see* Table 1.6.1, are provided, appropriate instructions are to be placed on the control station to shut down the system at fault.

6.2 Monitoring

6.2.1 Alarms and monitoring requirements are indicated in 6.2.2, 6.2.3 and Table 1.6.1.

Table 1.6.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication, *see* 6.1.6
	Failure	*See* 6.2.4
Steering power units, power	Failure	—
Steering motors	Overload Single phase	For alarm and running indication locations. *see* 6.3.2 and 6.3.3
Control system	Failure	*See* 6.2.4
Control system power	Failure	—
Steering gear hydraulic oil level	Low	Each reservoir to be be monitored. For Alarm locations, *see* 6.3.4.
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each each system is to be monitored, *see* Note
Hydraulic oil filter differential pressure	High	When oil filters are fitted

NOTE
This alarm is to identify the system at fault and is to be activated when (for example):
- position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

6.2.2 The angular position of the steering mechanism is to:
(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications are to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.
(b) Be recognisable in the steering unit compartment, if applicable.

6.2.3 The alarms described in Table 1.6.1 are to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by Pt 16, Ch 1,2.3.

6.2.4 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and fee back circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

6.3 Electrical equipment

6.3.1 Short circuit protection, and overload alarm and, in the case of polyphase circuits, an alarm to indicate failure of any one of the phases is to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

6.3.2 The alarms required by 6.3.1 are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

6.3.3 Indicators for running indication of each main and auxiliary motor are to be installed on the control station and at a suitable main machinery control position.

6.3.4 A low-level alarm is to be provided for each steering system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

6.3.5 Two exclusive circuits are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors.

6.3.6 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

6.3.7 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

6.3.8 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

6.3.9 These circuits are to be separated throughout their length as widely as is practicable.

6.3.10 Each main and auxiliary electric control system which is to be operated from the control station is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering unit power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected.

(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 7* Requirements for craft which are not required to comply with the HSC Code

7.1 Introduction

7.1.1 The requirements of Sections 1 to 6 of this Chapter apply, except where modified by this Section.

7.2 Design and performance

7.2.1 In craft over 50 m in length, the main steering system is to be power operated.

7.2.2 Service craft of length 50 m or less, or sailing yachts of length 50 m or less, may have manual steering. Where wheel steering is fitted, an alternative means of steering (which may be a hand tiller) is to be readily available, and the performance of both systems is to be in accordance with 7.2.6.

7.2.3 The main steering gear is to be capable of steering the craft at the maximum ahead speed and turning the rudder from hardover to hardover in 30 seconds.

7.2.4 Where wire rope steering leads are fitted, they are to be of suitable construction. Wire rope is to be stainless steel or suitably protected against corrosion and the strength of the rope is to be as follows:

$$\text{Breaking load} = \frac{d_{SU}^3}{100R} \text{ kN}$$

where

d_{SU} is the basic stock diameter at quadrant or tiller given by Table 3.2.7 in Pt 3, Ch 3, in mm.

R = radius of quadrant, or length of tiller arm, in mm.

7.2.5 Steering leads are to be as direct as possible, and sharp bends are to be avoided. Sheaves are to be of adequate diameter and designed to prevent the steering leads from jumping or jamming.

7.2.6 Means are to be provided for adjusting the tension in the steering leads.

7.2.7 Where considered necessary, an efficient locking or brake arrangement is to be fitted to keep the rudder steady when a change from one type of steering to the other is required.

7.2.8 Where manually operated steering is permitted, the effort required to operate the tiller or steering wheel is to be not more than 160 N under normal conditions.

7.3 Control and monitoring

7.3.1 The alarms and safeguards for yachts and service craft less than 24 m are to be adequate for the type of steering system employed, *see* Table 1.7.1.

Table 1.7.1 Alarms

Item	Alarm	Note
Angular position of the Steering Mechanism	—	Indication
Steering power units, power	Failure	—
Steering motors	Overload, single phase	Also running indication on bridge
Control system power	Failure	—
Steering gear hydraulic oil level	Low	—
Auto pilot	Failure	Running indication
Hydraulic oil temperature	High	Where oil cooler is fitted

7.3.2 The requirements of 6.3.5 do not apply to service craft less than 24 m.

7.4 Electrical equipment

7.4.1 Consideration will be given to the electrical control equipment of simple steering systems on service craft less than 24 m or yachts, *see* Pt 16, Ch 2.

Rules and Regulations for the Classification of Special Service Craft

Volume 7

Part 15

Piping Systems and Pressure Plant

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LIFE MATTERS

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■ *Section 1* Application

1.1 General

1.1.1 The requirements of this Chapter apply to the design and construction of piping systems including pipe fittings forming part of such systems.

■ *Section 2* Details to be submitted

2.1 Plans and information

2.1.1 At least three copies of the following plans and information are to be submitted.

2.1.2 Venting, sounding and drainage arrangements for all watertight compartments.

2.1.3 The following diagrammatic plans including details of the material and pipe dimensions/thickness:

- Bilge and ballast system including the capacities of the pumps on bilge service.
- Lubricating oil systems.
- Flammable liquids used for control and heating systems.
- Power transmission systems for services essential for safety or for the operation of the craft at sea.
- Cooling water systems for main and auxiliary services.
- Compressed air systems for main and auxiliary services.
- Steam systems with a design pressure above 7 bar.

2.1.4 Arrangement of oil fuel storage tanks with a capacity of over 0,5 m^3 where these do not form part of the structure of the craft.

2.1.5 Where it is intended to use plastic pipes for Class I, Class II and any Class III systems for which there are requirements in these Rules, details of the following:

(a) Properties of the materials.
(b) Operating conditions.
(c) Intended service and location.
(d) Pipes, fittings and joints.

2.1.6 Design details of the following components:

(a) Flexible hoses.
(b) Sounding devices.
(c) Resiliently seated valves.
(d) Expansion joints.
(e) Components of an unusual or novel nature.

2.1.7 The requirements for plans and information for the fire-fighting systems are given in Pt 17, Ch 1,1.2.3.

■ *Section 3* Class of pipes

3.1 General

3.1.1 Pipework systems are divided into three classes depending on the internal fluid and design temperature and pressure of the system.

3.1.2 Material test requirements for the different classes of pipe are detailed in the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

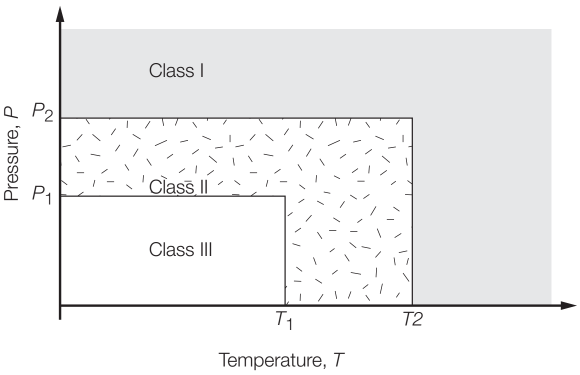
3.1.3 Acceptable jointing methods for the different classes of pipe are given in the appropriate Section of this Chapter. Material certificate requirements are given in Section 11.

3.1.4 The maximum design pressure and temperature for Class II and III systems is given in Table 1.3.1. To illustrate, *see* Fig. 1.3.1.

3.1.5 Class I pipes are to be used where either the maximum design pressure or design temperature exceeds that applicable to Class II pipes.

Table 1.3.1 Maximum pressure and temperature conditions for Class II and III piping systems

Piping system	Class II		Class III	
	p	*T*	*p*	*T*
	bar	°C	bar	°C
Steam	16,0	300	7,0	170
Flammable liquids (*see* Note)	16,0	150	7,0	60
Other media	40,0	300	16,0	200
NOTE Flammable liquids include: oil fuel, thermal oil and lubricating oil.				



NOTE
T_1 and P_1 correspond to the maximum temperatures and pressures for a Class III piping system and T_2 and P_2 to those for a Class II piping system depending on the service.

Fig. 1.3.1 Classes of piping system

3.1.6 Class III pipes may also be used for open ended piping, e.g. overflows, vents, boiler waste steam pipes, open-ended drains, sounding pipes, etc.

■ *Section 4*
Design symbols and definitions

4.1 Design symbols

4.1.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness
c = corrosion allowance, in mm
d = inside diameter of pipe, in mm, *see* 4.1.3
e = weld efficiency factor, *see* 4.1.4
p = design pressure, in bar, *see* 4.2
p_t = hydraulic test pressure, in bar
t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable
t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable
D = outside diameter of pipe, in mm, *see* 4.1.2
R = radius of curvature of a pipe bend at the centre line of the pipe, in mm
T = design temperature, in °C, *see* 4.3.1
σ = maximum permissible design stress, in N/mm^2.

4.1.2 The outside diameter, *D*, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

4.1.3 The inside diameter, *d*, is not to be confused with nominal pipe size, which is an accepted designation associated with outside diameters of standard rolling sizes.

4.1.4 The weld efficiency factor, *e*, is to be taken as 1,0 for seamless and electric resistance or induction welded steel pipes.

4.2 Design pressure

4.2.1 The design pressure, *p*, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve. In systems which have no safety valve or relief valve, the design pressure is to to be taken as 1,1 times the maximum working pressure.

4.2.2 The design pressure of piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

4.2.3 For design pressure of steering system components and piping, *see* Part 14.

4.3 Design temperature

4.3.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is it to be less than 50°C.

■ *Section 5*
Carbon and low alloy steels

5.1 General

5.1.1 The minimum thickness of steel pipes is to be determined by the formulae given in 5.1.2 and 5.1.3 except that in no case is it to be less than that shown in Table 1.5.1.

Table 1.5.1 Minimum thickness for steel pipes

External diameter D mm	Minimum pipe thickness mm
10,2–12	1,6
13,5–19	1,8
20–44,5	2,0
48,3–63,5	2,3
70–82,5	2,6
88,9–108	2,9
114,3–127	3,2
133–139,7	3,6
152,4–168,3	4,0
177,8 and over	4,5

NOTES
1. The thickness of air, overflow and sounding pipes for structural tanks is to be not less than 4,5 mm.
2. The thickness of bilge, ballast and general sea water pipes is to be not less than 4,0 mm.
3. The thickness of bilge, air, overflow and sounding pipes through ballast and oil fuel tanks, ballast lines through oil fuel tanks and oil fuel lines through ballast tanks is to be not less than 6,3 mm.
4. For air, bilge, ballast, oil fuel, overflow, sounding, and venting pipes as mentioned in Notes 1 to 3, where the pipes are efficiently protected against corrosion the thickness may be reduced by not more than 1 mm.
5. For air and sounding pipes the minimum thickness applies to the part of the pipe outside the tank but not exposed to weather. The section of pipe exposed to weather may be required to be suitably increased in thickness in accordance with statutory and loadline requirements as applicable.

5.1.2 The minimum thickness, t, of straight steel pressure pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\sigma e + p} + c \right) \frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c is obtained from Table 1.5.2, *see also* 5.1.4
σ may be obtained directly from Table 1.5.3 or from the formula given in 5.1.6.

Table 1.5.2 Values of corrosion allowance (c) for steel pipes

Piping service	c, in mm
Saturated steam systems	0,8
Compressed air systems	1,0
Hydraulic oil systems	0,3
Lubricating oil systems	0,3
Fuel oil systems	1,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

5.1.3 The minimum thickness, t_b, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma e + p} \right) \left(1 + \frac{D}{2{,}5R} \right) + c \right] \frac{100}{100 - a} \text{ mm}$$

where
symbols are as defined in 4.1.1
c and σ are obtained as in 5.1.2
in general, R is to be not less than $3D$.

5.1.4 For pipes passing through tanks, where the thickness has been calculated in accordance with 5.1.2 or 5.1.3, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with Table 1.5.2.

5.1.5 Where the pipes are efficiently protected against corrosion, the corrosion allowance, c, may be reduced by not more than 50 per cent.

Table 1.5.3 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2	Maximum permissible design stress, N/mm^2												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

5.1.6 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of E_t, R_{20} and S_R may be obtained from Chapter 6 of the Rules for Materials. Intermediate values may be obtained by interpolation.

5.1.7 Steel stub pipes between the shell plating and the sea valve are to be of short rigid construction, adequately supported and of substantial thickness.

5.2 Steel pipe joints

5.2.1 Joints in steel pipelines may be made by:

- Screwed on or welded on bolted flanges.
- Butt welds between pipes or between pipes and valve chests.
- Socket welded joints (up to 60,3 mm outside diameter).
- Threaded sleeve joints (parallel thread), *see also* 5.5.
- Special types of approved joints that have been shown to be suitable for the design conditions, *see also* 5.4.

5.2.2 All welding of pipes is to be in accordance with the requirements specified in Chapter 13 of the Rules for Materials.

5.2.3 Where pipes are joined by welding a suitable number of flanged joints are to be provided at suitable positions to facilitate installation and removal for maintenance.

5.2.4 Where welded pipes are protected against corrosion then the corrosion protection is to be applied after welding or the corrosion protection is to be made good in way of the weld damaged area.

5.2.5 Where it is not possible to make good the corrosion protection of the weld damaged area, then the pipe is to be considered to have no corrosion protection.

5.2.6 Where backing rings are used for welding pipes, then the effect of the flow obstruction of the backing ring and erosion/crevice corrosion of the backing ring is to be taken into account.

5.3 Welded-on flanges, butt welded joints and fabricated branch pieces

5.3.1 The dimensions and material of flanges and bolting, and the pressure-temperature rating of bolted flanges in pressure pipelines, in accordance with National or other established standards will be accepted.

5.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

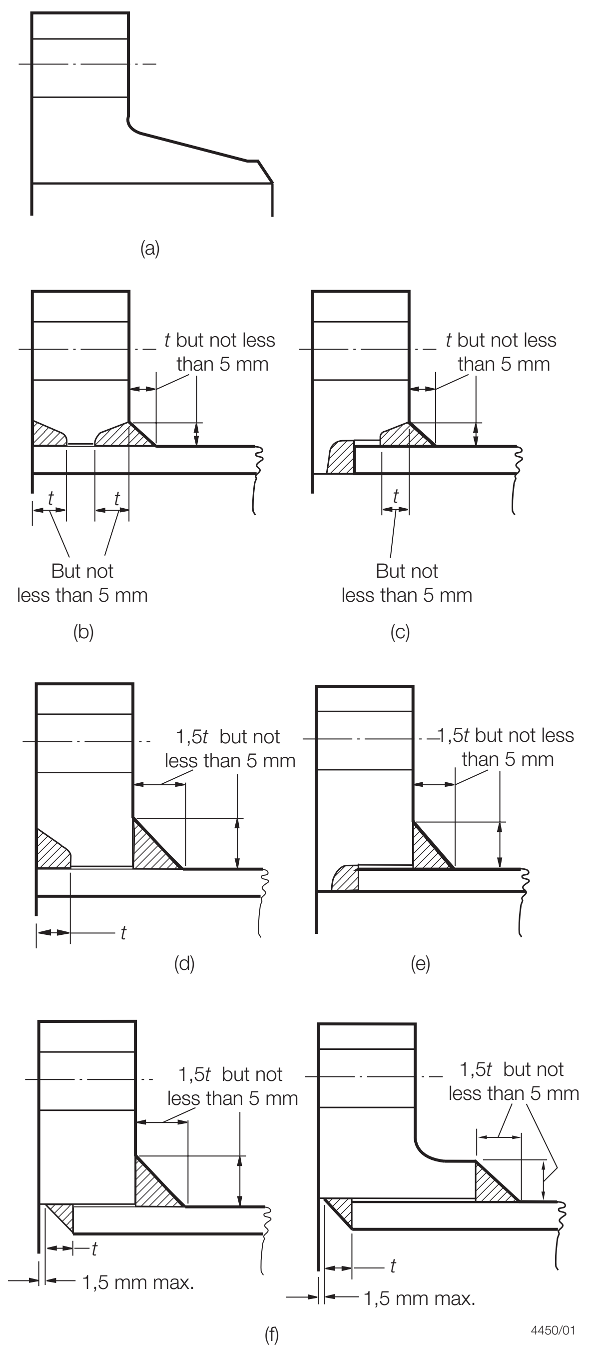


Fig. 1.5.1
Typical examples of welded flange connections

Table 1.5.4 Limiting design conditions for flange types

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

* No restriction for carbon steels

5.3.3 Typical examples of welded-on flange attachments are shown in Fig. 1.5.1, and limiting design conditions for flange types (a) to (f) are shown in Table 1.5.4.

5.3.4 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.3.5 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

5.3.6 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.3.7 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

5.4 Screwed fittings

5.4.1 Screwed fittings including compression fittings may be used in piping systems not exceeding 41 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then Lloyd's Register (hereinafter referred to as 'LR') may require the fittings to be subjected to special tests to demonstrate their suitability.

5.5 Threaded sleeve joints (parallel thread)

5.5.1 Threaded sleeve joints in accordance with National or other established standards may be used within the limits given in Table 1.5.5. They are not to be used in piping systems conveying flammable liquids.

Table 1.5.5 Limiting design conditions for threaded sleeve joints

Nominal bore	Maximum pressure	Maximum temperature
mm	bar (kgf/cm^2)	°C
≤ 25	12,0 (12,2)	260
> 25 ≤ 40	10,0 (10,2)	260
> 40 ≤ 80	8,5 (8,7)	260
> 80 ≤ 100	7,0 (7,1)	260

5.6 Socket weld joints

5.6.1 Socket weld joints may be used with carbon steel pipes not exceeding 60,3 mm outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur. *See also* Ch 4,7.3.9.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of 5.1.3 but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.7 Welded sleeve joints

5.7.1 Welded sleeve joints may be used in Class III systems only, subject to the restrictions and general dimensional requirements given in 5.6 for socket weld joints.

5.7.2 The pipe ends are to be located in the centre of the sleeve with a 1,5 to 2,0 mm gap.

5.8 Other mechanical couplings

5.8.1 Pipe unions, compression couplings, or slip-on joints, as shown in Fig. 1.5.2, may be used if type approved for the service conditions and the intended application. The type approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in Table 1.5.6 and dependence upon the Class of piping, with limiting pipe dimensions, is indicated in Table 1.5.7.

5.8.2 Where the application of mechanical joints results in a reduction in pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

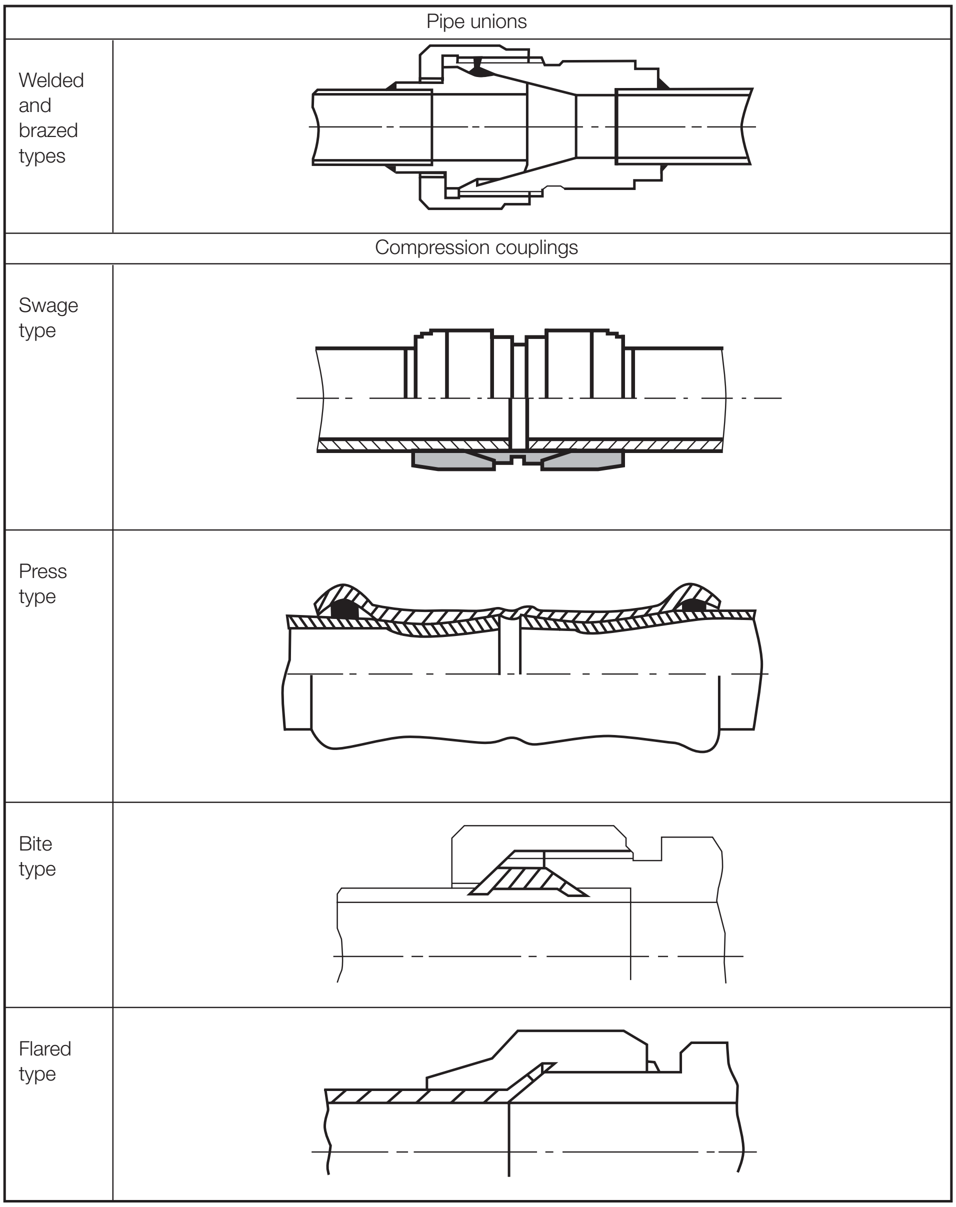


Fig. 1.5.2 Examples of mechanical joints (*see continuation*)

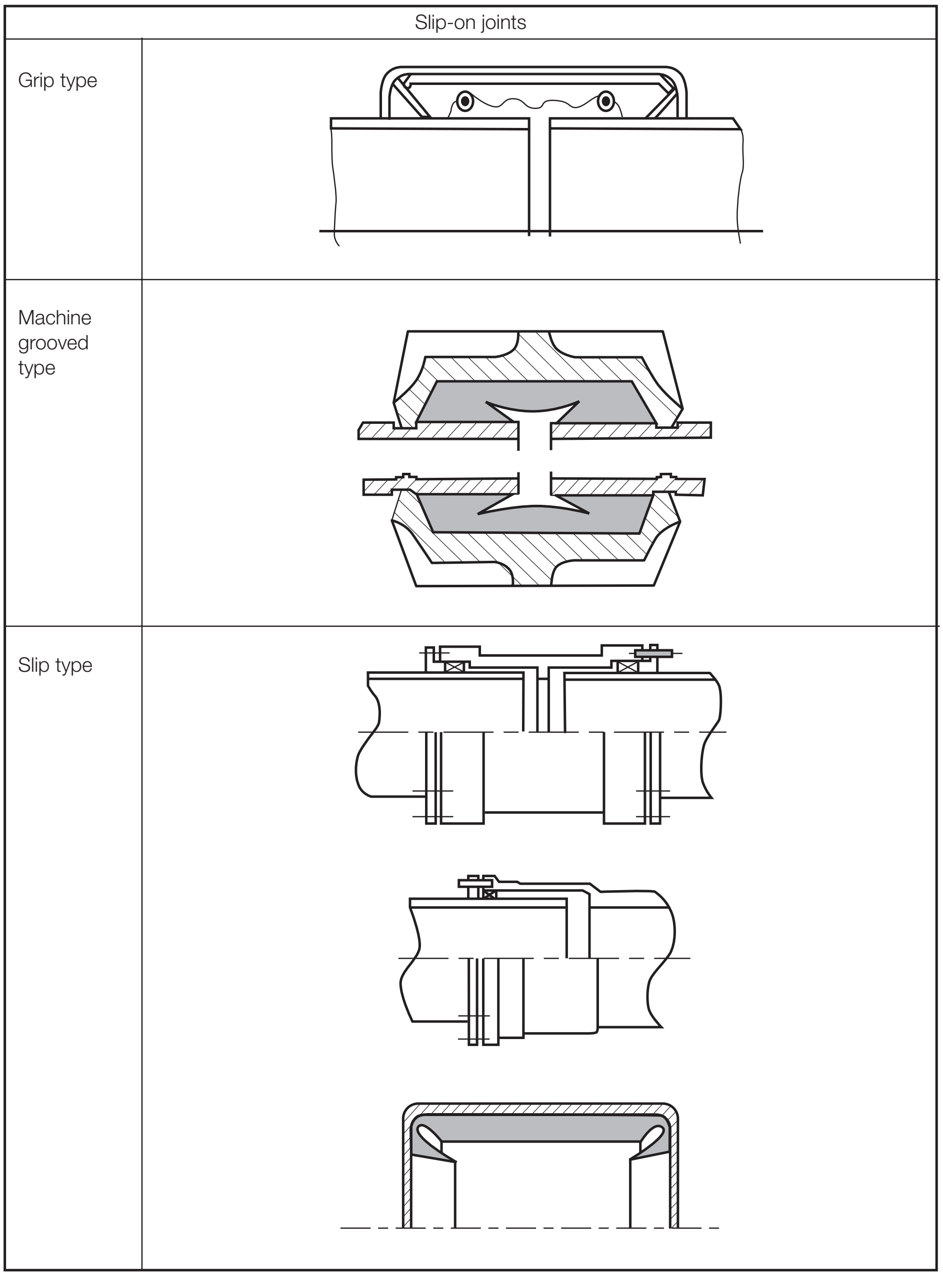


Fig. 1.5.2 Examples of mechanical joints (*conclusion*)

5.8.3 Construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects occurring during operation on board.

5.8.4 Materials of mechanical joints are to be compatible with the piping material and internal and external media.

5.8.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.8.6 In general, mechanical joints are to be of fire-resistant type where required by Table 1.5.6.

5.8.7 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

5.8.8 Mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.8.9 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

Table 1.5.6 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression couplings (6)	Slip-on joints
Flammable fluids (Flash point <60°)			
Cargo oil lines	+	+	+5
Crude oil washing lines	+	+	+5
Vent lines	+	+	+3
Inert gas			
Water seal effluent lines	+	+	+
Scrubber effluent lines	+	+	+
Main lines	+	+	+2,5
Distribution lines	+	+	+5
Flammable fluids (Flash point > 60°)			
Cargo oil lines	+	+	+5
Fuel oil lines	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea-water			
Bilge lines	+	+	+1
Fire main and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Condensate return	+	+	+1
Non-essential system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	—
Sounding/vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.> 60°C)	+	+	+2,3
Miscellaneous			
Starting/Control air (1)	+	+	—
Service air (non-essential)	+	+	+
Brine	+	+	+
CO_2 system	+	+	—
Steam	+	+	—

KEY
+ Application is allowed
— Application is not allowed

NOTES
1. Inside machinery spaces of Category A – only approved fire resistant types.
2. Not inside machinery spaces of Category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.
3. Approved fire resistant types.
4. Above freeboard deck only.
5. In pump rooms and open decks – only approved fire resistant types.
6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.

Table 1.5.7 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions			
Welded and brazed type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Compression couplings			
Swage type	–	–	+
Bite type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Flared type	+(OD ≤ 60,3 mm)	+(OD ≤ 60,3 mm)	+
Press type	–	–	+
Slip-on joints			
Machine grooved type	+	+	+
Grip type	–	+	+
Slip type	–	+	+
KEY + Application is allowed – Application is not allowed			

5.8.10 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

Section 6
Copper and copper alloys

6.1 General

6.1.1 Copper and copper alloy pipes are acceptable for a wide range of services, including bilge pipework and where non heat-sensitive material is required.

6.1.2 The maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of Chapter 9 of the Rules for Materials may be accepted up to 260°C.

6.1.3 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula but is not to be less than that shown in Table 1.6.1:

$$t = \left(\frac{pD}{20\sigma + p} + c\right)\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1

c = 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent

= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater

= 0 where the media are non-corrosive relative to the pipe material

σ may be obtained from Table 1.6.2.

Intermediate values may be obtained by linear interpolation.

Table 1.6.1 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameter)	Minimum overriding nominal thickness	
	Copper	Copper alloy
8 to 10	1,0	0,8
12 to 20	1,2	1,0
25 to 44,5	1,5	1,2
50 to 76,1	2,0	1,5
88,9 to 108	2,5	2,0
133 to 159	3,0	2,5
193,7 to 267	3,5	3,0
273 to 457,2	4,0	3,5
508 and over	4,5	4,0

6.1.4 The minimum thickness t_b, of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending:

$$t_b = \left[\left(\frac{pD}{20\sigma + p}\right)\left(1 + \frac{D}{2{,}5R}\right) + c\right]\frac{100}{100 - a} \text{ mm}$$

where

symbols are as defined in 4.1.1

c and σ are obtained as in 6.1.3

in general, R is to be not less than $3D$.

6.1.5 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressing or other approved fabrications.

Table 1.6.2 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm²	Permissible stress, N/mm² Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	—	—	—	—
Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	—	—	—	—
90/19 Copper-nickel iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

6.1.6 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried.

6.1.7 Where silver brazing is used, strength is to be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing is to contain not less than 49 per cent silver.

6.1.8 The use of copper-zinc brazing alloy is not permitted.

6.2 Heat treatment

6.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of manufacture and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated.

■ *Section 7* Cast iron

7.1 General

7.1.1 Grey cast iron valves and fittings will, in general, be accepted in Class III piping systems except as stated in 7.1.5. Grey cast iron valves and fittings may be accepted in the Class II steam systems referred to in Table 1.3.1 but the design pressure or temperature is not to exceed 13 bar or 220°C, respectively.

7.1.2 Spheroidal or nodular graphite iron castings for valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of $5,65\sqrt{S_o}$, where S_o is the actual cross-sectional area of the test piece.

7.1.3 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

7.1.4 Where the elongation is less than the minimum required by 7.1.2, the material is, in general, to be subject to the same limitations as grey cast iron.

7.1.5 Grey cast iron is not to be used for the following:

- Valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Shell valves and fittings, *see* Ch 2,3.1.
- Valves fitted on the collision bulkhead.

■ *Section 8* Plastics

8.1 General

8.1.1 Proposals to use plastics pipes will be considered in relation to the properties of the materials, the operating conditions and the intended service and location. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

8.1.2 Attention is also to be given to *Guidelines for the Application of Plastics Pipes on Ships* contained in IMO Resolution A.753(18).

8.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems.

8.1.4 Plastics pipes are not acceptable for oil fuel, lubricating oil or other flammable liquid systems in machinery spaces, cargo holds and other spaces of high fire risk.

8.1.5 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

8.1.6 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in 8.4, are to be taken into account.

8.1.7 The use of plastics pipes may be restricted by statutory requirements of the National Authority of the country in which the craft is to be registered.

8.2 Design and performance criteria

8.2.1 Pipes and fittings are to be of robust construction and are to comply with a national or other established standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

8.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of 8.3.

8.2.3 Depending on the service and location, the fire safety aspects such as fire endurance, and fire protection coatings, are to meet the requirements of 8.4.

8.2.4 Plastics piping is to be electrically conductive when:
(a) Carrying fluids capable of generating electrostatic charges.
(b) Passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of 8.5, *see also* Pt 16, Ch 2,1.13.

8.3 Design strength

8.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

8.3.2 In service, the pipe is not to be subjected to a pressure greater than the nominal internal pressure pN_i.

8.3.3 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{P_{st}}{4}$$

$$pN_i \leq \frac{P_{1t}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar
p_{1t} = long term hydrostatic test failure pressure (100 000 hours), in bar.

Due to the length of time stipulated for the long term test, testing may be carried out over a reduced period of time and the results extrapolated using a suitable standard such as ASTM D2837 and ASTM D1598.

8.3.4 The nominal external pressure, pN_e of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{P_{col}}{3}$$

where

p_{col} = pipe collapse pressure in bar

The pipe collapse pressure is to be not less than 3 bar.

8.3.5 Piping is to meet the design requirements of 8.3.2 and 8.3.4 over the range of service temperature it will experience.

8.3.6 High temperature limits and pressure reductions relative to nominal pressures are to be in accordance with a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum temperature of deflection under load is not to be less than 80°C, *see also* Ch 14,4 of the Rules for Materials.

8.3.7 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

8.3.8 For guidance, typical temperature and pressure limits are indicated in Tables 1.8.1 and 1.8.2. The Tables are related to water service only.

8.3.9 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

8.3.10 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

8.4 Fire performance criteria

8.4.1 Where plastics pipes are used in systems essential for the safe operation of the craft, or for containing combustible fluids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings are to be of a type which have been fire endurance tested, *see also* 8.2.3.

8.4.2 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

8.5 Electrical conductivity

8.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc., is not to exceed 0,1 MΩ/m, *see also* 8.2.4.

Table 1.8.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar						
		–20°C to 0°C	30°C	40°C	50°C	60°C	70°C	80°C
PVC	10		7,5	6				
	16		12	9	6			
ABS	10	7,5	7,5	7	6			
	16	12	12	10,5	9	7,5	6	
HDPE	10	7,5	6					
	16	12	9,5	6				

Abbreviations:

PVC Polyvinyl chloride
ABS Acrylonitrile – butadiene – styrene
HDPE High density polyethylene

Table 1.8.2 Typical temperature and pressure limits for glass fibre reinforced epoxy (GRE) and glass fibre reinforced polyester (GRP) pipes

Min. temperature of deflection under load of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50°C to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

8.6 Installation and construction

8.6.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

8.6.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding, laminating, adhesive bonding or other approved means.

8.6.3 Sufficient mechanical joints are to be provided to enable the pipes to be readily removed.

8.6.4 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

8.6.5 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck by means of metallic bulkhead pieces. The bulkhead pieces are to be protected against corrosion and so constructed to be of a strength equivalent to the intact bulkhead; attention is drawn to 8.6.1. Details of the arrangements are to be submitted for approval.

8.6.6 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also* Pt 16, Ch 2,1.13.

8.7 Testing

8.7.1 The hydraulic testing of pipes and fittings is to be in accordance with 14.1.2. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by Ch 14,4.9 of the Rules for Materials may be replaced by testing carried out in accordance with the requirements stipulated in a National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided there is an effective quality system in place complying with the requirements of Ch 14,4.4 of the Rules for Materials and the testing is completed to the satisfaction of the LR Surveyor.

8.7.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ.

Section 9
Austenitic stainless steel

9.1 General

9.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of austenitic steels in sea water systems, *see* 16.3.4.

9.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in 5.1.2 or 5.1.3 using a corrosion allowance of 0,8 mm. Values of the 1,0 per cent proof stress and tensile strength of the material for use in the formula in 5.1.6 may be obtained from Table 6.5.2 in Chapter 6 of the Rules for Materials.

9.1.3 Where stainless steel is used in lubricating oil and hydraulic oil systems, the corrosion allowance may be reduced to 0 mm.

9.1.4 In no case is the thickness of stainless steel pipes to be less than that shown in Table 1.9.1.

Table 1.9.1 Minimum thickness for austenitic stainless steel pipes

Standard pipe sizes (outside diameter)			Minimum nominal thickness
mm		mm	mm
10,2	to	17,2	1,0
21,3	to	48,3	1,6
60,3	to	88,9	2,0
114,3	to	168,3	2,3
219,1			2,6
273,0			2,9
323,9	to	406,4	3,6
over	406,4		4,0

NOTE
The external diameters and thicknesses have been selected from ISO-Standard 1127:1980. Diameters and thicknesses according to other National or International Standards may be accepted.

9.1.5 Joints in stainless steel pipework may be made by any of the techniques described in 5.2 to 5.7.

9.1.6 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

Section 10
Aluminium alloy

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In craft of aluminium construction, aluminium alloy may also be used for air and sounding pipes for oil fuel, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces or cargo holds for conveying oil fuel, lubricating oil or other flammable liquids, or for bilge suction pipework within machinery spaces.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0
150	3,4
200	3,8
250 and over	4,2

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat. The use of aluminium alloy with appropriate insulation will be considered when it has been demonstrated that the arrangements provide equivalent structural and integrity properties compared to steel. In open and exposed locations, where the insulation material is likely to suffer from mechanical damage, suitable protection is to be provided.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in Table 1.10.1.

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

Section 11
Material certificates

11.1 Metallic materials

11.1.1 Materials for Class I and II piping systems and components as defined in Table 1.3.1, also for shell valves and fittings and fittings on the collision bulkhead are to be manufactured and tested in accordance with the Rules for Materials.

11.1.2 Ferrous castings and forgings for Class I and II piping systems are to be produced at a works approved by LR.

11.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

11.1.4 The Manufacturer's materials test certificate will be accepted for all classes of piping and components in lieu of an LR materials certificate where the maximum design conditions are less than shown in Table 1.11.1.

Table 1.11.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	Working temperature °C	DN = Nominal Diameter, mm P_W = Working Pressure, bar
Carbon and low alloy steel. Stainless steel. Spheroidal or nodular cast iron.	< 300	$DN < 50$ or $P_W \times DN < 2500$
Copper alloy	< 200	$DN < 50$ or $P_W \times DN < 1500$

11.2 Non-metallic materials

11.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with Chapter 14 of the Rules for Materials.

Section 12
Requirements for valves

12.1 General

12.1.1 The design, construction and operational capability of valves are to be in accordance with an acceptable National or International Standard appropriate for the piping system. Where valves are not in accordance with an acceptable Standard, details are to be submitted for consideration.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of an essential service.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their control gear, are to be of steel construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut unless this is readily obvious.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves and cocks are to be fitted with legible nameplates, and, unless otherwise specifically mentioned in the Rules, the valves and cocks are to be fitted in places where they are at all times readily accessible.

12.1.8 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.9 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

12.1.10 Additional requirements for shell valves are given in Ch 2,3.

12.2 Valves with remote control

12.2.1 All valves which are provided with remote control are to be arranged for local manual operation, independent of the remote operating mechanism.

12.2.2 In the case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

12.3 Resiliently seated valves

12.3.1 Valves, having isolation or sealing components sensitive to heat, are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of an essential service.

12.3.2 Where the valves are of the diaphragm type, they are not acceptable as shut off valves at the shell plating.

12.3.3 Resiliently seated valves are not to be used in main or auxiliary machinery spaces as branch or direct bilge suction valves or as pump suction valves from the main bilge line (except where the valve is located in the immediate vicinity of the pump and in series with a metal seated non-return valve. The non-return valve is to be fitted on the bilge main side of the resiliently seated valve). Where they are used in other locations and within auxiliary machinery spaces having little or no fire risk they should be of an approved fire safe type and used in conjunction with a metal seated non-return valve.

12.3.4 Resiliently seated valves are not acceptable for use in fire water mains unless they have been satisfactorily fire tested.

■ *Section 13* Requirements for flexible hoses

13.1 General

13.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

13.1.2 For the purpose of approval for the applications in 13.2, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration.

13.1.3 The use of hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

13.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

13.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

13.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

13.1.7 The number of flexible hoses in piping systems mentioned in this Section is to be kept to a minimum and to be limited for the purpose stated in 13.2.1.

13.1.8 Where flexible hoses are intended for conveying flammable fluids in piping systems that are in close proximity to hot surfaces, electrical installation or other sources of ignition, the risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

13.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

13.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

13.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:

(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing.

13.2 Applications for rubber hoses

13.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

13.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and sea-water cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed.

13.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, oil fuel, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for oil fuel supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

13.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

13.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

13.3 Design requirements

13.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

13.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with 5.8 as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

13.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by 13.4 are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

13.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

13.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

13.4 Testing

13.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

13.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing*.
- ISO 6803 – *Rubber and plastics hoses and hose assemblies – Hydraulic pressure impulse test with flexing*.
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods*.
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench*.
- ISO 10380 – *Pipework – Corrugated metal hoses and hose assemblies*.

Other Standards may be accepted where agreed by LR.

13.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an international standard (*see* Note) to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

NOTE:
The International Standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 14*
Hydraulic tests on pipes and fittings

14.1 Hydraulic tests before installation on board

14.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure. Further, all steam, feed, compressed air and oil fuel pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

14.1.2 The test pressure is to be 1,5 times the design pressure, as defined in 4.2.

14.1.3 Shell valves and valves on the collision bulkhead are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating of the valve at ambient temperature.

14.2 Testing after assembly on board

14.2.1 Oil fuel piping is to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 3,5 bar.

14.2.2 Where pipes specified in 14.1.1 are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of 14.2.1 after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

14.2.3 The hydraulic test required by 14.2.2 may be omitted provided non–destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results.

14.2.4 Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

Cross-reference

See also Ch 2,2.4 for testing after installation.

Section 15
Requirements for small craft which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1 to 13 apply, except where modified by this Section.

15.2 Details to be submitted

15.2.1 Details of oil fuel storage tanks over 0,25 m^3, where these do not form part of the structure of the craft, are to be submitted.

15.2.2 Design details of the components listed in 2.1.6 are not required.

15.3 Materials

15.3.1 Materials for which no provision is made in this Chapter may be accepted provided that they comply with an acceptable National or International Standard and are satisfactorily tested as may be considered necessary. Manufacturer's material test certificates are not required unless the material is of unusual or special specification.

15.3.2 Shell valves and cocks, inlet chests, distance pieces and other sea connections are to be of approved ductile material. Due attention is to be paid to the compatibility of the material with that of the shell. Ordinary grey cast iron is not acceptable.

15.4 Aluminium alloy

15.4.1 Proposals for the use of aluminium alloy pipes in bilge systems in machinery spaces will be considered, provided that a single failure in any section of the pipe does not render the whole system inoperable.

15.4.2 Aluminium alloy pipes may be used for fire-fighting systems outside machinery spaces in locations of low fire risk.

15.5 Plastics pipes

15.5.1 IMO Resolution A.753(18) *Guidelines for the Application of Plastics Pipes on Ships* does not apply.

15.5.2 The requirements of 8.1.5 do not apply but where plastics pipes are used for bilge and cooling water services they are to be of a type which has been approved by LR. However, fire endurance testing is not required.

15.5.3 Where plastics pipes are used in bilge systems in machinery spaces, a single failure in any section of the pipe is not to render the whole system inoperable.

15.6 Copper and copper alloys

15.6.1 Where copper and copper alloy pipes are in accordance with an acceptable National Standard/ Specification which is applicable to the intended service or media, Table 1.6.1 need not be applied.

Section 16
Guidance notes on metal pipes for water services

16.1 General

16.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

16.1.2 In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

16.2 Materials

16.2.1 Materials used in sea water piping systems include:
- Galvanised steel.
- Stainless and duplex steel, *see also* 16.3.4.
- Steel pipes lined with rubber, plastics or stoved coatings.
- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium alloy.
- Aluminium brass.
- Bronze.
- Approved plastics.

16.2.2 Selection of materials should be based on:
- The ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered;
- Compatibility with the other materials in the system, such as valve bodies and casings, in order to minimise bimetallic corrosion;
- The ability to resist selective corrosion, e.g. dezincification of brass, dealuminification of aluminium brass and graphitisation of cast iron;
- The ability to resist stress corrosion and corrosion fatigue, and;
- The amenability to fabrication by normal practices.

16.3 Steel pipes

16.3.1 Steel pipes should be protected against corrosion and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

16.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

16.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

16.3.4 Austenitic stainless steel pipes are not recommended for salt water services in polluted waters or where stagnant conditions exist. Steel of specification 316L or better may give satisfactory service in water circulating systems for clean sea water.

16.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc., and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

16.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

16.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

16.4 Copper and copper alloy pipes

16.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

16.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

16.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

16.5 Flanges

16.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

16.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

16.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

16.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

16.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

16.5.6 The use of a copper-zinc brazing alloy is not permitted.

16.6 Water velocity

16.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc., selected to suit the conditions.

16.6.2 The water velocity in copper pipes should not exceed 1 m/s.

16.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

Galvanised steel	3,0 m/s
Aluminium brass	3,0 m/s
90/10 copper-nickel-iron	3,5 m/s
70/30 copper-nickel	5,0 m/s.

16.7 Fabrication and installation

16.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions in the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth.

16.7.2 Pipe bores should be smooth and clean.

16.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

16.7.4 Pipe bends should be of as large a radius as possible, and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

16.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

16.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

16.7.7 Strainers should be provided at the inlet to sea-water systems.

16.8 Metal pipes for fresh water services

16.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

16.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

16.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

16.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

16.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in 'once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

Section

■ *Section 1* General

1.1 Application

1.1.1 The requirements of Sections 1 to 11 of this Chapter apply to all craft which are required to satisfy the relevant design and construction regulations of the HSC Code.

1.1.2 Special requirements for multi-hull craft are given in Section 12.

1.1.3 Additional requirements for Passenger (B) Craft are given in Section 13.

1.1.4 Requirements for craft of less than 24 m not required to comply with the HSC Code are given in Section 14.

1.1.5 Requirements for craft of 24 m or more not required to comply with the HSC Code are given in Section 15.

1.1.6 Additional requirements for yachts that are 500 gt or more are given in Section 16.

1.1.7 The requirements for air cushion vehicles are given in Section 17.

1.1.8 In addition to the requirements of this Chapter, attention should be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

1.1.9 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules.

1.2 Details to be submitted

1.2.1 The plans and information detailed in Chapter 1 are to be submitted before commencement of work.

1.3 Watertight and non-watertight decks

1.3.1 For the purpose of this Section, a non-watertight deck covered by a weathertight structure may be taken as equivalent to a watertight deck. For definitions of the terms watertight and weathertight, *see* Pt 3, Ch 1.

■ *Section 2* Construction and installation

2.1 Installation

2.1.1 All pipes for essential services are to be secured in position to prevent chafing or lateral movement.

2.1.2 Long or heavy lengths of pipe are to be supported by bearers so that no undue load is carried by pipe connections or pumps and fittings to which they are attached.

2.2 Provision for expansion

2.2.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes.

2.2.2 Where expansion pieces are fitted, arrangements are to be provided to protect against over extension and compression. The adjoining pipes are to be suitably aligned, supported, guided and anchored. Where necessary, expansion pieces of the bellows type are to be protected against mechanical damage.

2.3 Miscellaneous requirements

2.3.1 All pipes situated in cargo spaces, chain lockers or other positions where they are liable to mechanical damage are to be efficiently protected.

2.3.2 So far as practicable, pipelines, including exhaust pipes from engines, are not to be routed in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of fluids, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary.

2.4 Testing after installation

2.4.1 After installation on board, all steam, hydraulic, compressed air and other piping systems covered by Ch 1,2.1.3 together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

■ *Section 3*
Shell valves and fittings (other than those on scuppers and sanitary discharges)

3.1 Construction

3.1.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell or to fabricated water boxes attached to the shell.

3.1.2 Distance pieces of short rigid construction and made of approved material may be fitted between the valve and shell. The thickness of such pipes is to be equivalent to shell thickness.

3.1.3 The arrangements are to be such that the section of pipe immediately inboard of the shell valve may be removed without affecting the watertight integrity of the hull.

3.1.4 The valves are to be in accordance with the general requirements for valves given in Ch 1,12.

3.1.5 Shell valves are to be manufactured from non-heat sensitive materials and tested in accordance with the appropriate requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). Special consideration will be given to the use of other materials on craft of aluminium or composite construction. Where the valves are manufactured from spheroidal or nodular graphite cast iron they are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR'). Grey cast iron is not acceptable.

3.1.6 Shell valves are to be fitted in accessible positions and are to be capable of being operated from positions which are readily accessible in case of influx of water to the compartment.

3.1.7 Valve hand wheels and cock handles are to be suitably retained on the spindles. Means are to be provided to indicate whether the valve or cock is open or closed.

3.1.8 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

3.1.9 Shell valves are to be hydraulically tested before installation in accordance with Ch 1,14.

■ *Section 4*
Bilge pumping and drainage systems

4.1 General

4.1.1 Arrangements are to be made for draining all watertight compartments other than those intended for permanent storage of fluids. Where drainage is not considered necessary, drainage arrangements may be omitted provided the safety of the craft is not impaired.

4.1.2 Pumping arrangements are to be provided having suctions and means of drainage so arranged that any water within any watertight compartment of the craft or any watertight section of any compartment, can be pumped out through at least one suction under all possible conditions of list and trim in the maximum assumed damage condition.

4.1.3 The bilge pumping system is to be designed to prevent water flowing from one watertight compartment to another.

4.1.4 The necessary valves for controlling the bilge suctions are to be capable of being operated from above the watertight deck.

4.1.5 Where a bilge main is not fitted and a compartment is served by a fixed submersible pump in accordance with Section 10, then an additional emergency means of pumping out the compartment is to be provided, *see* Section 6.

4.1.6 Small compartments may be drained by individual hand pump suctions.

4.1.7 The intactness of watertight bulkheads is not to be impaired by the fitting of scuppers discharging to machinery spaces or tunnels from adjacent compartments situated below the highest watertight deck.

4.1.8 Any unattended space for which bilge pumping arrangements are required is to be provided with a bilge level alarm.

4.1.9 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist.

■ *Section 5* Bilge drainage of machinery spaces with a propulsion prime mover

5.1 General

5.1.1 The bilge drainage arrangements are to comply with Section 4, except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions under all possible conditions of list and trim in the maximum assumed damage condition.

5.1.2 Where a bilge main is fitted, one of the suctions referred to in 5.1.1 is to be a branch bilge suction i.e. a suction connected to the bilge main. The second bilge suction is to be a direct bilge suction as detailed in 8.6.

5.1.3 Where a bilge main is not fitted, the branch bilge suction referred to in 5.1.2 may be replaced by a suction from a submersible bilge pump. The second bilge suction is to be either a second submersible bilge pump or a direct bilge suction as detailed in 8.6.

5.1.4 The emergency bilge drainage arrangements detailed in Section 6 are to be provided where either 5.1.2 or 5.1.3 applies.

5.2 Additional bilge suctions

5.2.1 Additional bilge suctions may be required for the drainage of wells or other recesses.

■ *Section 6* Emergency bilge drainage

6.1 Emergency bilge drainage

6.1.1 In machinery spaces the emergency bilge suction required by 4.1.5 and 5.1.4 is to be led to the largest available power pump, which is not a bilge, propulsion or oil pump, from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve with an extended spindle and hand wheel situated above the floor plating.

6.1.2 As an alternative to 6.1.1, or in compartments other than machinery spaces, the emergency bilge pumping arrangements may be provided by a portable submersible self-priming pump of capacity not less than that required by 8.3.5.

6.1.3 The pump referred to in 6.1.2 together with its suction and delivery hoses is to be stored in a locker marked 'For emergency use only' and is to be available for immediate use. Arrangements to facilitate safe handling under adverse conditions are to be provided. If the pump is electrically driven it is to be supplied from the emergency switchboard.

■ *Section 7* Size of bilge suction pipes

7.1 Bilge main

7.1.1 Where a bilge main is fitted, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

B = breadth of craft, in metres
D = moulded depth to the watertight deck, in metres
L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

7.2 Branch bilge suctions

7.2.1 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 12{,}5 \text{ mm}$$

where

B and D are as defined in 7.1.1
C = length of compartment, in metres.

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

■ *Section 8* Pumps on bilge service

8.1 Number of pumps

8.1.1 For craft fitted with a bilge main, at least two power bilge pumping units are to be provided. One of these units may be worked from the main engines and the other is to be independently driven.

8.1.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is not less than that required by 8.3.2.

8.1.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 8.1.1.

8.1.4 For craft fitted with fixed submersible bilge pumps, one pump is to be provided for each watertight compartment.

8.1.5 For the bilge pumping requirements for multi-hull craft, *see* Section 12.

8.2 General service pumps

8.2.1 The bilge pumping units or pumps required by 8.1 may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for bilge duty when required. For the use of bilge pumping units for fire-extinguishing duties, *see* Part 17.

8.3 Capacity of pumps

8.3.1 Each bilge pumping unit is to be connected to the bilge main and is to be capable of giving a speed of water through the Rule size of bilge main of not less than 2 m/s.

8.3.2 To achieve the flow velocity required by 8.3.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m{}^2 \quad \text{m}^3/\text{hour}$$

where

d_m is as defined in 7.1.1.

Q = Rule minimum capacity, in m^3/hour.

8.3.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

8.3.4 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3} d_m{}^2 \quad \text{m}^3/\text{hour}$$

where

d_m is as defined in 7.1.1.

Q_t = Rule minimum total capacity, in m^3/hour.

8.3.5 The capacity Q_n of each submersible bilge pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N - 1)} \quad \text{m}^3/\text{hour}$$

where

N = number of fixed submersible pumps

Q_t is as defined in 8.3.4

Q_n = Rule minimum submersible pump capacity, in m^3/hour

Q_n is in no case to be less than 8 m^3/hour.

8.4 Self-priming pumps

8.4.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps.

8.5 Pump connections

8.5.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

8.5.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

8.6 Direct bilge suctions

8.6.1 The direct bilge suction in the machinery space required by 5.1.2 and referred to in 5.1.3 is to be led to an independent power pump, and the arrangements are to be such that the direct suction can be used independently of the main bilge line suctions.

8.6.2 The machinery space direct bilge suction is not to be of a diameter less than that required for the machinery space branch bilge suction and arranged as detailed in 8.6.1.

■ *Section 9* Bilge main arrangements and materials

9.1 General

9.1.1 Bilge mains, branch bilge suctions and bilge overboard discharge arrangements within machinery spaces are to be of steel or other equivalent material.

9.1.2 Where bilge suction pipework outside machinery spaces is manufactured from material sensitive to heat then the arrangements are to be such that pipe failure in one compartment will not render the bilge suction pipework in another compartment inoperable.

9.1.3 Bilge pipework is to be mounted inboard such that in the event of the maximum assumed damage the pipework will remain intact.

9.2 Prevention of communication between compartments

9.2.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests
- Bilge suction hose connections, whether fitted direct to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to the main bilge line.

9.3 Isolation of bilge system

9.3.1 Bilge suction pipes are to be entirely separate from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

9.4 Bilge suction strainers

9.4.1 The open ends of bilge suctions are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

■ *Section 10*
Submersible bilge pump arrangements

10.1 General

10.1.1 Arrangements are to be such that at least two automatic non-return devices are fitted between the overboard discharge and the watertight space being served by the pump.

10.1.2 One of these devices is to be an automatic non-return valve situated at or near the shell and the other may be a pipework loop taken up to the highest practicable point below the watertight deck. The arrangements are to be effective in the maximum assumed damaged condition.

■ *Section 11*
Air, overflow and sounding pipes

11.1 Air pipes

11.1.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

11.1.2 Air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

11.1.3 Air pipes to oil fuel, lubricating oil and other tanks containing flammable liquids which are located in or pass through compartments of high fire risk or on open deck are to be of steel or other equivalent material.

11.2 Termination of air pipes

11.2.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the watertight deck. Air pipes to oil fuel tanks, cofferdams and all tanks which can be pumped up are to be led to the open.

11.2.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces.

11.2.3 The open ends of air pipes to oil fuel tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

11.2.4 The location and arrangement of air pipes for oil fuel service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rainwater.

11.3 Gauze diaphragms

11.3.1 The open ends of air pipes to oil fuel tanks are to be fitted with a wire gauze diaphragm of non-corrodible material which can be readily removed for cleaning or renewal.

11.3.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe, *see* 11.6.

11.4 Air pipe closing appliances

11.4.1 Closing appliances fitted to tank air pipes are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, *see also* Pt 3, Ch 4,12.3.

11.4.2 Air pipe closing devices are to be of a type acceptable to LR and are to be tested in accordance with a National or International Standard recognised by LR. The flow characteristic of the closing device is to be determined using water, *see* 11.6.1.

11.4.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

11.4.4 Air pipe automatic closing devices shall be so designed that they will withstand both ambient conditions as indicated in Pt 9, Ch 1, 4.4 and designed working conditions, and be suitable for use at inclinations up to and including ± 40°.

11.4.5 Air pipe automatic closing devices shall be constructed to allow inspection of the closure and the inside of the casing, as well as changing the seals.

11.4.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

11.4.7 Air pipe automatic closing devices are to be self-draining.

11.4.8 The clear area through an air pipe closing device in the open position shall be at least equal to the area of the inlet.

11.4.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim.

11.4.10 The maximum allowable tolerances for wall thickness of floats should not exceed ±10 per cent of thickness.

11.4.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

11.4.12 Casings of air pipe closing devices are to be of approved metallic materials adequately protected against corrosion.

11.4.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

11.4.14 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, for example the inner chamber area above the air pipe, plus an overlap of 10° or more either side) an additional harder coating should be applied. This is to be an aluminium bearing epoxy, or other equivalent coating, applied over the zinc.

11.5 Nameplates

11.5.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

11.6 Size of air pipes

11.6.1 For every tank which can be filled by on-board pumps, the total cross-sectional area of the air pipes and the air pipe closing devices is to be such that when the tank is overflowing at the maximum pumping capacity available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

11.6.2 In all cases, whether a tank is filled by on-board pumps or other means, the total cross-sectional area of the pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

11.6.3 Air pipes are to be generally not less than 38 mm bore. In the case of small gravity filled tanks smaller bore pipes may be accepted but in no case is the bore to be less than 25 mm.

11.7 Overflow pipes

11.7.1 For all tanks which can be pumped up, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipes is less than that required by 11.6.

(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

11.7.2 In the case of oil fuel tanks, lubricating oil tanks and other tanks containing flammable liquids, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means is to be provided to indicate when overflowing is occurring.

11.7.3 Overflow pipes are to be self draining under normal conditions of trim.

11.7.4 Where overflow sight glasses are provided, they are to be in a vertical dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality and be adequately protected from mechanical damage. Overflow sight glasses are not permitted in oil fuel systems for craft required to comply with the HSC Code.

11.8 Combined air and overflow systems

11.8.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point above the waterline in the maximum assumed damage condition.

11.8.2 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

11.9 Sounding arrangements

11.9.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

11.9.2 Sounding devices of an approved type (i.e. level gauge or remote reading level device) may be used in lieu of sounding pipes.

11.9.3 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

11.9.4 Where fitted, sounding pipes are to be as straight as practicable, and if curved to suit the structure of the craft, the curvature is to be sufficiently easy to permit the ready passage of the sounding rod or chain.

11.9.5 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

11.9.6 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

11.9.7 Sounding pipes are to be not less than 32 mm bore.

11.10 Termination of sounding pipes

11.10.1 Except as permitted by 11.11, sounding pipes are to be led to positions above the bulkhead deck which are at all times accessible and, in the case of oil fuel tanks, cargo oil tanks and lubricating oil tanks, the sounding pipes are to be led to safe positions on the open deck.

11.10.2 For closing requirements, *see also* Pt 3, Ch 4,12.3.1.

11.11 Short sounding pipes

11.11.1 In machinery spaces, where it is not practicable to extend sounding pipes as mentioned in 11.10 short sounding pipes extending to readily accessible positions above the platform may be fitted.

11.11.2 Short sounding pipes are not permitted in machinery spaces for tanks containing oil fuel or other flammable oils used in power transmission systems, control and activating systems and heating systems, except as permitted by 11.13.6.

11.11.3 Short sounding pipes may be fitted to tanks used for the storage, distribution and utilisation of lubricating oil in machinery spaces. These sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.12 Elbow sounding pipes

11.12.1 In passenger craft, elbow sounding pipes are not permitted.

11.12.2 Elbow sounding pipes are not to be used for deep tanks, unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any subdivision and damage stability requirements that may apply.

11.12.3 The elbows are to be of heavy construction and adequately supported.

11.13 Sounding arrangements for oil fuel, lubricating oil and other flammable liquids

11.13.1 Safe and efficient means of ascertaining the amount of oil in any storage tank are to be provided.

11.13.2 For oil fuel, lubricating oil and other flammable liquids, closed sounding devices are preferred. Design details of such devices are to be submitted and they are to be tested after fitting on board, to the satisfaction of the Surveyors.

11.13.3 If closed sounding devices are fitted, failure of the device or over filling of the tank is not to result in the release of tank contents. In passenger craft and yachts that are 500 gt or more, such means are not to require penetration below the top of the tank.

11.13.4 Where sounding pipes are used they are not to terminate in any space where risk of ignition or spillage from the sounding pipe might arise. In particular they are not to terminate in public spaces or crew accommodation. Additionally for oil fuel tanks they are not to terminate in machinery spaces. Terminations are to be provided with a suitable means of closure and provision to prevent spillage during refuelling/refilling operations.

11.13.5 Where gauge glasses are used they are to be of the flat type of heat resisting quality, adequately protected from mechanical damage and fitted with self closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

11.13.6 In yachts and service craft which are not required to comply with the HSC Code, short sounding pipes extending to well-lighted, readily accessible positions above the platform may be fitted in machinery spaces and tunnels. Sounding pipes are to be fitted with cocks having parallel plugs with permanently attached handles located such that, on being released, they automatically close the cocks.

11.13.7 For yachts that are 500 gt or more, where short sounding pipes serve tanks containing oil fuel, an additional sounding device of approved type is to be fitted. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned in 11.13.6, in order to ensure that the sounding pipe is not under pressure from oil fuel before opening up the sounding pipe.

■ *Section 12*
Requirements for multi-hull craft

12.1 General

12.1.1 The requirements of Sections 2 to 11 apply to multi-hull craft except where modified by the requirements of this Section.

12.2 Drainage of raft void spaces

12.2.1 Arrangements are to be provided for venting, sounding and draining raft void spaces generally as required by Sections 1 to 11.

12.2.2 Where the raft void space is located above the water line in the maximum assumed damage condition then it may be drained directly overboard through scuppers fitted with non-return valves.

12.2.3 Raft void spaces which are not located above the water line in the worst expected damage condition are to be provided with pumping arrangements in accordance with Section 4.

12.3 Size of bilge suction pipes

12.3.1 Where a bilge main is fitted in each hull, its internal diameter d_m is to be not less than that required by the following formula:

$$d_m = 1{,}68 \sqrt{L (B + D)} + 25 \text{ mm}$$

where

B = breadth of a hull in metres

D = moulded depth to the watertight deck, in metres

L = length of craft, in metres

The actual internal diameter of the bilge main may be rounded off to the nearest pipe size of a recognised standard, but d_m is in no case to be less than 50 mm.

12.3.2 The diameter d_b of branch bilge suction pipes is to be not less than that required by the following formula:

$$d_b = 2{,}15 \sqrt{C (B + D)} + 12{,}5 \text{ mm}$$

where

C = length of compartment, in metres

B and D are as defined in 12.3.1

The actual internal diameter of branch bilge suction pipes may be rounded off to the nearest pipe size of a recognised standard, but d_b is in no case to be less than 25 mm.

12.4 Capacity and number of pumps on bilge main services

12.4.1 Each power bilge pump should be capable of pumping water through the required size of bilge main at a speed of not less than 2 m/s.

12.4.2 To achieve the flow velocity required by 12.4.1, the capacity Q of each bilge pumping unit or bilge pump is to be not less than that required by the following formula:

$$Q = \frac{5{,}75}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.3 Not less than two power bilge pumping units taking suction from the bilge main in each hull are to be provided.

12.4.4 Where the bilge system in each hull is entirely separate then two bilge pumping units in each hull are to be provided.

12.4.5 Where fixed submersible bilge pumps are fitted, the total capacity Q_t of the pumps in each hull is to be not less than that required by the following formula:

$$Q_t = \frac{13{,}8}{10^3} d_m^2 \text{ m}^3\text{/hour}$$

where

d_m is as defined in 12.3.1.

12.4.6 The capacity Q_n of each submersible pump is to be not less than that required by the following formula:

$$Q_n = \frac{Q_t}{(N - 1)} \text{ m}^3\text{/hour}$$

where

N = number of fixed submersible pumps in each hull

Q_t is as defined in 12.4.5

Q_n is in no case to be less than 8 m^3/hour.

Section 13
Additional requirements for Passenger (B) Craft

13.1 Bilge pumping arrangements

13.1.1 At least three power bilge pumping units are to be fitted connected to the bilge main, one of which may be driven by the propulsion machinery.

13.1.2 For multi-hull craft the bilge pumping units are to be capable of taking suction from the bilge main in any hull of the craft.

13.1.3 The arrangements are to be such that at least one power bilge pump is to be available for use in all flooding conditions which the craft is required to withstand as follows:

(a) one of the required bilge pumps is to be an emergency pump of a reliable submersible type having a source of power located above the waterline after the craft has sustained the maximum assumed damage; or

(b) the bilge pumps and their sources of power are to be so distributed throughout the length of the craft that at least one pump in an undamaged compartment will be available.

13.1.4 Alternatively fixed submersible bilge pumps may be provided in accordance with the requirements of 8.3.4 for monohull craft or 12.4.5 for multihull craft.

13.1.5 Distribution boxes, cocks and valves in connection with the bilge pumping system are to be so arranged that, in the event of flooding, one of the bilge pumps may take suction from any compartment.

13.1.6 Damage to a pump or its pipe connecting to the bilge main is not to put the bilge system out of action.

13.1.7 When in addition to the main bilge pumping system an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating in any compartment under the maximum assumed flooding conditions. In that case only the valves necessary for the operation of the emergency system need be capable of remote operation.

13.1.8 All cocks and valves referred to in 13.1.5 which can be remotely operated are to have their controls at their place of operation clearly marked and are to be provided with means to indicate whether they are open or closed.

Section 14
Requirements for small craft which are not required to comply with the HSC Code

14.1 General

14.1.1 These requirements replace Sections 1 to 10, 12 and 13 of this Chapter. In general the requirements of Section 11 are to be complied with, however 11.4.1 and 11.9.3 do not apply.

14.1.2 Bilge and cooling water pipework systems are to be of an approved material, *see* Ch 1,15.

14.2 Shell valves and fittings

14.2.1 All sea inlet and overboard discharges are to be provided with shut off valves or cocks arranged in positions where they are readily accessible at all times.

14.2.2 Where valves, cocks, inlet chests, distance pieces and other sea connections are made of steel or other approved materials of low corrosion resistance, they are to be suitably protected against wastage.

14.3 Fittings for steel and aluminium hulls

14.3.1 All suction and discharge valves and cocks secured direct to the plating are to be fitted with spigots passing through the plating, but spigots on the valves and cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the plating.

14.4 Fittings for wood and glass reinforced plastics hulls

14.4.1 The openings in the shell or planking are to have suitably reinforced areas or pads into which the attached fittings are to be spigoted.

14.4.2 Valves or fittings are to be secured with an external ring under the bolt heads. The ring is to be of copper nickel alloy, bronze, dezincification resistant brass or other material approved for use in sea-water.

14.4.3 Valves or cocks up to 50 mm bore may be attached to spigot pieces or hull fittings having an external collar and internal nut.

14.4.4 Valves or cocks over 50 mm bore are to be flanged and attached as per 14.4.2.

14.5 Bilge pumping arrangements

14.5.1 An efficient bilge pumping system is to be fitted having suctions and means of drainage so arranged that any water which may enter any compartment can be pumped overboard.

14.5.2 The system is to be tested on completion of the craft to ensure that all limber holes are free and that under normal conditions of trim any bilge water can drain to an appropriate suction.

14.5.3 The arrangement of pumps, valves, cocks, pipes and sea connections is to be such as to prevent water entering the craft accidentally or the possibility of one watertight compartment being placed in communication with another.

14.5.4 Readily accessible strum boxes are to be fitted at the open ends of tail pipes.

14.5.5 The perforations in the strum boxes are to be not greater than 10 mm diameter and the combined area is to be not less than twice that required for the bilge suction pipe.

14.5.6 Where a collision bulkhead is fitted, the fore peak dry space is to be drained either by a branch suction to the main bilge line or by a manual pump. Alternatively, it may be drained to the adjacent compartment by means of a self closing drain cock which is to be readily accessible under all conditions.

14.5.7 Where a bilge main is fitted, the internal diameter d of the main and the branch suction pipes is to be not less than that required by the following formula:

$$d = \frac{L}{1,2} + 25 \text{ mm}$$

where

L = length of craft, in metres.

14.6 Pumps on bilge service and their connections

14.6.1 Not less than one power pump and one manual bilge pump are to be provided. Both pumps are to be arranged to take suction from the bilge main or suction valve chest as applicable.

14.6.2 The power driven pumps may be used for other services such as deck washing, fire extinguishing or standby cooling water duty but not for pumping oil fuel or other flammable liquids.

14.6.3 The total capacity Q_t of the bilge pumps is to be not less than required by the following formula:

$$Q_t = 1,5\,(d - 25) - 6,7 \text{ m}^3\text{/hour}$$

where

d is as defined in 14.5.7

Q_t is in no case to be less than 3 m^3/hour.

14.6.4 A reduction in capacity of one pump may be permitted provided the deficiency is made good by an excess capacity of the other pump or by an additional pump. In no case is this deficiency to be more than 40 per cent of the Rule capacity.

14.6.5 Pumps on bilge service are to be of the self-priming type.

14.6.6 The bilge pumps are to be connected to a common bilge line provided with a branch connection to each compartment.

14.6.7 A non-return valve is to be fitted between each bilge pump and the bilge main.

14.6.8 Non-return valves are to be fitted in each branch bilge suction from the main bilge line.

14.6.9 Power pumps may be driven by the main engine, an auxiliary engine or by an electric motor.

14.6.10 The power pump is to be provided with a suction enabling it to pump directly from the engine space in addition to the suction from the main bilge line. This direct bilge suction is to be controlled by a screw down non-return valve or equivalent.

14.6.11 Manual bilge pumps are to be capable of being operated from readily accessible positions above the waterline.

14.6.12 As an alternative to fitting a bilge main, individual submersible pumps may be fitted. In this case the arrangements are to be in accordance with the requirements of Sections 8, 10 and 12 of this Chapter, as applicable.

■ *Section 15*
Requirements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

15.1 General

15.1.1 The requirements of Sections 1, 2, 3, 11 and 12 of this Chapter are generally applicable. The remaining Sections 4 to 10 of this Chapter concerning the requirements for bilge pumping and drainage systems are replaced by the requirements given in 15.2 to 15.28.

15.2 Bilge systems and pumping

15.2.1 Where it is intended to carry vehicles with fuel in their tanks having a flashpoint less than 60°C for their own propulsion and having re-fuelling facilities for such vehicles or when only providing re-fuelling facilities, a separate bilge system is to be provided.

15.2.2 The bilge system is to be designed to prevent pumping of flammable liquids through piping and pumps in machinery, accommodation or any other spaces where a source of ignition may exist.

15.3 Drainage of compartments, other than machinery spaces

15.3.1 All craft are to be provided with efficient pumping plant having the suctions and means for drainage so arranged that any water within any compartment of the craft, or any watertight section of any compartment, can be pumped out through at least one suction when the craft is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

15.3.2 In the case of dry compartments, the suctions required by 15.3.1 are, except where otherwise stated, to be branch bilge suctions, i.e. suctions connected to a main bilge line.

15.4 Tanks and cofferdams

15.4.1 All tanks (including double bottom tanks), whether used for water ballast, oil fuel or liquid cargoes, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank.

15.4.2 In general, the drainage arrangements are to be in accordance with 15.3. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

15.4.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the main bilge line.

15.5 Fore and after peaks

15.5.1 Where the peaks are used as tanks, a power pump suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

15.5.2 Where the peaks are not used as tanks, and main bilge line suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps. Drainage of the after peak may be effected by means of a self-closing cock fitted in a well lighted and readily accessible position.

15.5.3 Pipes piercing the collision bulkhead are to be fitted with suitable valves secured to the bulkhead. The valves are to be operable from above the freeboard deck.

15.6 Spaces above fore peaks, after peaks and machinery spaces

15.6.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand or power pump suctions.

15.6.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand or power pump bilge suctions.

15.6.3 The compartments referred to in 15.6.2 may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel or machinery space and fitted with self-closing cocks situated in well lighted and visible positions.

15.7 Maintenance of integrity of bulkheads

15.7.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck.

15.7.2 No drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

15.8 Bilge drainage of machinery space

15.8.1 The bilge drainage arrangements in the machinery space are to comply with 15.3 except that the arrangements are to be such that any water which may enter this compartment can be pumped out through at least two bilge suctions when the craft is on an even keel, and is either upright or has a list of not more than 5°. One of these suctions is to be a branch bilge suction, i.e. a suction connected to the main bilge line, and the other is to be a direct bilge suction, i.e. a suction led direct to an independent power pump.

15.9 Separate machinery spaces

15.9.1 Where the machinery space is divided by watertight bulkheads to separate the auxiliary engine room(s) from the main engine room, the bilge drainage arrangements for the auxiliary engine room(s) are to be the same as for compartments, other than machinery spaces, referred to in 15.3.1.

15.9.2 In addition to the requirements of 15.9.1, at least one direct suction, led to an independent power pump, is to be fitted in each compartment.

15.10 Machinery space with double bottom

15.10.1 Where the double bottom extends the full length of the machinery space and forms bilges at the wings, it will be necessary to provide one branch and one direct bilge suction at each side.

15.10.2 Where the double bottom plating extends the full length and breadth of the compartment, one branch bilge suction and one direct bilge suction are to be led to each of two bilge wells, situated one at each side.

15.10.3 Where there is no double bottom and the rise of floor is not less than 5°, one branch and one direct bilge suction are to be led to accessible positions as near to the centreline as practicable.

15.11 Machinery space – Emergency bilge drainage

15.11.1 In addition to the bilge suctions detailed in 15.8 and 15.9, an emergency bilge suction is to be provided in each main machinery space. This suction is to be led to the main cooling water pump from a suitable low level in the machinery space and is to be fitted with a screw-down non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

15.11.2 Where two or more cooling water pumps are provided, each capable of supplying cooling water for normal power, only one pump need be fitted with an emergency bilge suction.

15.11.3 Where main cooling water pumps are not suitable for bilge pumping duties, the emergency bilge suction is to be led to the largest available power pump, which is not a bilge pump.

15.11.4 Emergency bilge suction valve nameplates are to be marked 'For emergency use only'.

15.12 Sizes of bilge suction pipes

15.12.1 The diameter, d_m, of the main bilge line is to be not less than that required by the following formula, to the nearest 5 mm, but in no case is the diameter to be less than that required for any branch bilge suction:

$$d_m = 1{,}68\sqrt{L\,(B + D)} + 25 \text{ mm}$$

where

d_m = internal diameter of main bilge line, in mm
B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L = Rule length of craft in metres.

15.12.2 The diameter d_b, of branch bilge suction pipes to cargo and machinery spaces is to be not less than required by the following formula, to the nearest 5 mm, but in no case is the diameter of any suction to be less than 50 mm:

$$d_b = 2{,}15\sqrt{C\,(B + D)} + 25 \text{ mm}$$

where

d_b = internal diameter of branch bilge suction, in mm
C = length of compartment, in metres
B and D are as defined in 15.12.1.

15.12.3 The direct bilge suctions in the machinery space are not to be of a diameter less than that required for the main bilge line.

15.12.4 For sizes of emergency bilge suctions, *see* 15.11.

15.13 Distribution chest branch pipes

15.13.1 The area of each branch pipe connecting the bilge main to a distribution chest is to be not less than the sum of the areas required by the Rules for the two largest branch bilge suction pipes connected to that chest, but need not be greater than that required for the main bilge line.

15.14 Pumps on bilge service and their connections

15.14.1 At least two power bilge pumping units are to be provided in the machinery space. One of these units may be worked from the main engines and the other is to be independently driven.

15.14.2 Each unit may consist of one or more pumps connected to the main bilge line, provided that their combined capacity is adequate.

15.14.3 A bilge ejector in combination with a high pressure sea-water pump may be accepted as a substitute for an independent bilge pump as required by 15.14.1.

15.14.4 Special consideration will be given to the number of pumps for small craft and, in general, if there is a class notation restricting a small craft to harbour or river service, a hand pump may be accepted in lieu of one of the bilge pumping units.

15.15 General service pumps

15.15.1 The bilge pumping units, or pumps, required by 15.14 may also be used for ballast, fire or general service duties of an intermittent nature, but they are to be immediately available for bilge duty when required.

15.16 Capacity of pumps

15.16.1 Each bilge pumping unit is to be connected to the main bilge line and is to be capable of giving a speed of water through the Rule size of main bilge pipe of not less than 122 m/min.

15.16.2 The capacity of each bilge pumping unit or bilge pump is to be not less than required by the following formula:

$$Q = \frac{5{,}75}{10^3}\, d_m^{\,2}$$

where

d_m = Rule internal diameter of main bilge line, in mm
Q = capacity, in m^3/hour.

15.16.3 Where one bilge pumping unit is of slightly less than Rule capacity, the deficiency may be made good by an excess capacity of the other unit. In general, the deficiency is to be limited to 30 per cent.

15.17 Self-priming pumps

15.17.1 All power pumps which are essential for bilge services are to be of the self-priming type, unless an approved central priming system is provided for these pumps. Details of this system are to be submitted.

15.17.2 Cooling water pumps having emergency bilge suctions need not be of the self-priming type.

15.18 Pump connections

15.18.1 The connections at the bilge pumps are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

15.18.2 Pumps required for essential services are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any pumps so connected is unaffected by the other pumps being in operation at the same time.

15.19 Direct bilge suctions

15.19.1 The direct bilge suctions in the machinery space are to be led to independent power pumps, and the arrangements are to be such that these direct suctions can be used independently of the main bilge line suctions.

15.20 Main bilge line suctions

15.20.1 Suctions from the main bilge line, i.e. branch bilge suctions, are to be arranged to draw water from any hold or machinery compartment within the craft, excepting small spaces such as those mentioned in 15.5 and 15.6 where manual pump suctions are accepted, and are not to be of smaller diameter than that required by the formula in 15.12.2.

15.21 Prevention of communication between compartments

15.21.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another, or of dry cargo spaces, machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge valve distribution chests.
- Bilge suction hose connections, whether fitted directly to the pump or on the main bilge line.
- Direct bilge suctions and bilge pump connections to main bilge line.

15.22 Isolation of bilge system

15.22.1 Bilge pipes which are required for draining cargo or machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried. This does not, however, exclude a bilge ejection connection, a connecting pipe from a pump to its suction valve chest, or a deep tank suction pipe suitably connected through a change-over device to a bilge, ballast or oil line.

15.23 Machinery space suctions – Mud boxes

15.23.1 Suctions for bilge drainage in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the bilges and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency bilge suctions.

15.24 Hold suctions – Strum boxes

15.24.1 The open ends of bilge suctions in holds and other compartments outside machinery spaces and tunnels are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

15.25 Tail pipes

15.25.1 The distance between the foot of all bilge tail pipes and the bottom of the bilge well is to be adequate to allow a full flow of water and to facilitate cleaning.

15.26 Location of fittings

15.26.1 Bilge valves, cocks and mud boxes are to be fitted at, or above, the machinery space platforms.

15.26.2 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

15.27 Bilge pipes in way of double bottom tanks

15.27.1 Bilge suction pipes are not to be led through double bottom tanks if it is possible to avoid doing so.

15.27.2 Bilge pipes which have to pass through these tanks are to have a minimum wall thickness of 6,3 mm. The thickness of pipes made from material other than steel will be specially considered.

15.27.3 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

15.28 Hold bilge non-return valves

15.28.1 Where non-return valves are fitted to the open ends of bilge suction pipes in cargo holds in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 16* Additional requirements for yachts that are 500 gt or more

16.1 General

16.1.1 Yachts that are 500 gt or more are to comply with Section 15 of this Chapter and in addition the following requirements.

16.2 Location of bilge pumps and bilge main

16.2.1 At least three power bilge pumps are to be provided, one of which may be operated from the main engines. Wherever practicable they are to be located in separate watertight compartments which will not readily be flooded by the same damage. If the engines are in two or more watertight compartments, the bilge pumps are to be distributed throughout these compartments so far as possible.

16.2.2 Where compliance with 16.2.1 is impractical, two independently driven bilge pumps may be accepted provided they are located in separate watertight compartments. If both pumps are necessarily located in the machinery space then one is to be of the submersible type with its source of power located above the bulkhead deck.

16.2.3 The bilge main is to be so arranged that no part is situated nearer the side of the craft than *B*/5, measured at right angles to the centreline at the level of the deepest sub-division load line, where *B* is the breadth of the craft.

16.2.4 Where any bilge pump or its pipe connection to the bilge main is situated outboard of the *B*/5 line, then a non-return valve is to be provided in the pipe connection at the junction with the bilge main.

16.2.5 Each independent bilge pump is to have a direct bilge suction from the space in which it is situated, but not more than two such suctions are required in any one space. The suctions are to be arranged such that each side of the space is fitted with at least one suction.

16.3 Prevention of communication between compartments in the event of damage

16.3.1 Provision is to be made to prevent the compartment served by any bilge suction pipe being flooded, in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, where any part of a branch bilge pipe is situated outboard of the *B*/5 line or in a duct keel, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

16.4 Arrangement and control of bilge valves

16.4.1 Distribution boxes, valves and cocks in connection with the bilge pumping arrangements are to be so arranged that, in the event of flooding, one of the bilge pumps may be operative on any compartment.

16.4.2 Where there is only one system of pipes common to all pumps, the arrangements are to be such that if the machinery space or other compartment is flooded then it is possible to operate the necessary valves and cocks in order to take suction from that compartment. For this purpose it may be necessary to arrange for remote control of the bilge suction valves from above the bulkhead deck.

16.4.3 Where, in addition to the main bilge pumping system, an emergency bilge pumping system is provided, it is to be independent of the main system and so arranged that a pump is capable of operating on any compartment under flooding conditions. In this case, only the valves and cocks necessary for the operation of the emergency system need to be capable of being operated from above the bulkhead deck.

16.4.4 All valves and cocks mentioned in 16.4.2 which can be operated from above the bulkhead deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

16.5 Cross flooding arrangements

16.5.1 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from above the bulkhead deck.

Section 17
Requirements for Air Cushion Vehicles

17.1 General

17.1.1 At least three copies of the following diagrammatic plans are to be submitted together with a general description of each system, indicating operating pressures and temperatures, etc., safety devices incorporated and means of protection against corrosion and contamination:

- Oil fuel.
- Lubricating oil.
- Hydraulic and pneumatic systems.
- Pumping arrangements for draining and trimming.
- Air filtering to power units.

17.1.2 Reference is to be made to the *Guidance Notes and Requirements for the Classification of Air Cushion Vehicles (ACV) 1970*.

■ *Section 1*
Application

1.1 Applicability of requirements

1.1.1 The requirements of Sections 2 to 8 of this Chapter apply to piping systems on mono-hull and multi-hull craft except where modified by Sections 9 to 11 as applicable.

1.1.2 Special requirements for multi-hull craft are given in Section 9.

1.1.3 These requirements satisfy the relevant design and construction requirements of the HSC Code. They are also applicable to yachts and service craft of more than 24 m not required to comply with the Code.

1.1.4 Requirements for Passenger (A) Craft are given in Section 10.

1.1.5 Requirements for small craft not required to comply with the HSC Code are given in Section 11.

1.1.6 In addition to the requirements of this Chapter, attention is to be given to any relevant statutory requirements of the National Authority of the country in which the craft is to be registered.

■ *Section 2*
General requirements

2.1 General

2.1.1 The maximum working pressure in any part of a fluid system is not to be greater than the design pressure.

2.1.2 Where the design pressure of a system component, such as a valve or a fitting, is less than that for the pipe or tubing, the system pressure is to be limited to the lowest of the component design pressures. Every system which may be exposed to pressures higher than the design pressure is to be safeguarded by appropriate relief devices.

2.1.3 Materials used in piping systems are to be compatible with the fluid conveyed and due regard given to the risk of fire. Non-metallic piping material may be permitted in certain systems, provided the integrity of the hull and watertight decks and bulkheads is maintained.

2.1.4 The design of pipework systems is to be in accordance with the requirements of Chapter 1.

■ *Section 3*
Oil fuel storage

3.1 Flash point

3.1.1 The flash point (closed cup test) of oil fuel for use in craft classed for unrestricted service is in general to be not less than 60°C. For emergency generator engines, a flash point of not less than 43°C is permissible.

3.1.2 Oil fuel with a flash point lower than 60°C may be used in craft intended for restricted service where it can be demonstrated that the temperature of machinery spaces will always be 10°C below the flash point of the oil fuel.

3.1.3 The use of oil fuel with a flash point below 43°C is not recommended. However, oil fuel with a lower flash point, but not lower than 35°C, may be used in gas turbines only subject to compliance with the provisions specified in Section 5.

3.1.4 Proposals for the use or carriage of oil fuel with a lower flash point will be specially considered.

3.2 Oil fuel storage arrangements

3.2.1 Tanks containing oil fuel are to be separated from passenger, crew and baggage compartments by vapour-proof enclosures or cofferdams which are suitably ventilated and drained.

3.2.2 Oil fuel tanks are not to be located in or adjacent to major fire hazard areas.

3.2.3 Oil fuel is not to be carried forward of the area for which public spaces or crew accommodation are permitted.

3.2.4 No oil fuel tank is to be situated where spillage or leakage therefrom can constitute a hazard by falling on heated surfaces.

3.2.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any oil fuel tank is to be provided, *see also* Ch 2,11.9 to 11.12.

3.2.6 Oil fuel tanks are to be provided with self-closing valves or cocks for draining water from the bottom of the tanks.

3.2.7 As far as practicable, all parts of the oil fuel system containing heated oil under pressure exceeding 2 bar are not to be placed in a concealed position such that defects and leakage cannot be readily observed. The machinery spaces in way of such parts of the oil fuel system are to be adequately illuminated.

3.2.8 Oil fuel tanks are to be provided with oil-tight drip trays of sufficient capacity having suitable drainage arrangements.

3.2.9 In general oil fuel tanks are not to be used for carriage of water ballast. Where this is unavoidable the fuel transfer system is to be isolated from the ballast system and either oily water separating equipment is to be installed, or discharge to shore facilities provided, in accordance with the requirements of the *International Convention for the Prevention of Pollution from Ships* in force.

3.3 Oil fuel storage arrangements for yachts and service craft of 24 m or greater in length, which are not required to comply with the HSC Code

3.3.1 Oil fuel tanks are normally to be located outside machinery spaces and other areas of major fire hazard.

3.3.2 Where structural tanks are located adjacent to machinery spaces they are to be arranged such that the area of the tank common with the machinery space is kept to a minimum. In craft constructed of aluminium or other heat sensitive material the tanks are to be suitably protected against the effect of fire in the machinery space.

3.3.3 Where free standing tanks are fitted in machinery spaces they are to be of steel or equivalent material and positioned in an oil tight drip tray of ample size having suitable drainage arrangements to a spill oil tank.

3.3.4 For yachts that are 500 gt or more, free standing oil fuel tanks are not to be fitted in machinery spaces, *see* Pt 17, Ch 3,3.17.3.

3.3.5 The requirements of 3.2.4 to 3.2.8 are to be complied with. Where free standing tanks are fitted they are to comply with the requirements of 11.3.1 to 11.3.3.

3.4 Unattended machinery

3.4.1 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, the requirements of 3.4.2 to 3.4.5 apply.

3.4.2 Where daily service tanks are filled automatically or by remote control, means are to be provided to prevent overflow spillages.

3.4.3 Other equipment which treats flammable liquid automatically, such as oil fuel purifiers, are to have arrangements to prevent spillage of the liquid through overflow or malfunction of seals.

3.4.4 Alarms are to be provided for purifier broken water seal and high oil inlet temperature.

3.4.5 Where daily service oil fuel tanks or settling tanks are fitted with heating arrangements, a high temperature alarm is to be provided if the flash point of the oil can be exceeded. This alarm is to be separate from the temperature control system.

3.4.6 Oil fuel service tanks are to be provided with high and low level alarms. Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted.

3.4.7 Oil and gas dual-fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

■ *Section 4* Oil fuel systems

4.1 Oil fuel supply to main and auxiliary engines

4.1.1 Two or more filters are to be fitted in the oil fuel supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered oil fuel to the engines.

4.2 Booster pumps

4.2.1 Where an oil fuel booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

4.2.2 The standby pump is to be connected ready for immediate use, but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

4.3 Fuel valve cooling pumps

4.3.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with 4.2.1 and 4.2.2.

4.4 Transfer pumps

4.4.1 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use. The standby pump may be a manual pump. Alternatively, emergency connections may be made to another suitable power driven pump.

4.5 Control of pumps

4.5.1 All independently driven oil fuel transfer and pressure pumps are to be capable of being stopped locally and from a position outside of the space in which they are located. The remote stop position is always to be accessible in the event of fire occurring in the space in which these pumps are located.

4.6 Relief valves on pumps

4.6.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and to effectively limit the pump discharge pressure to the design pressure of the system.

4.7 Pump connections

4.7.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.8 Low pressure pipes

4.8.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be suitable for a working pressure of not less than 7 bar.

4.9 Valves on deep tanks and their control arrangements

4.9.1 Every oil fuel suction pipe from a storage, settling or daily service tank situated above the double bottom, and every oil fuel levelling pipe, is to be fitted with a valve or cock secured to the tank.

4.9.2 In machinery spaces such valves and cocks are to be capable of being closed locally and from positions outside these spaces which will always be accessible in the event of fire occurring in these spaces. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.9.3 In the case of tanks of less than 0,5 m^3, consideration will be given to the omission of remote controls for craft not required to comply with the HSC Code.

4.9.4 Every oil fuel suction pipe which is led into the machinery spaces, from a deep tank outside these spaces, is to be fitted in the machinery space with a valve controlled as in 4.9.2 except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

4.9.5 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in 4.9.2.

4.10 Filling arrangements

4.10.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.10.2 Provision is to be made against over-pressure in the filling pipelines. Any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11 Precautions against fire

4.11.1 Pipes, valves and couplings conveying flammable fluids are to be installed, screened or otherwise suitably protected, to avoid spray or leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. The number of joints in such systems is to be kept to a minimum.

■ *Section 5* Low flash point fuels

5.1 General

5.1.1 For craft having oil fuel with a flash point below 43°C the arrangements for the storage, distribution and utilisation of the oil fuel are to be such that the safety of the craft and persons on board is preserved, having regard to fire and explosion hazards. The arrangements are to comply with Sections 3, 4 and 5.1.2 to 5.1.6.

5.1.2 Tanks for the storage of such oil fuel are to be located outside any machinery space and at a distance of not less than 760 mm inboard from the shell and bottom plating, and from decks and bulkheads.

5.1.3 The spaces in which oil fuel tanks are located are to be mechanically ventilated using exhaust fans providing not less than six air changes per hour. The fans are to be such as to avoid the possibility of ignition of flammable gas air mixtures. Suitable wire mesh guards are to be fitted over inlet and outlet ventilation openings. The outlets for such exhausts are to discharge to a safe position.

5.1.4 A fixed vapour detection system is to be installed in each space through which oil fuel lines pass, with alarms provided at a continuously manned control station.

5.1.5 Safe and efficient means of ascertaining the amount of oil fuel contained in any tank is to be provided. Gauge glasses are not to be used. Other means of ascertaining the amount of oil fuel contained in any tank may be permitted if such means do not require penetration below the top of the tank, and providing their failure or overfilling of the tanks will not permit the release of oil fuel.

5.1.6 Vessel to shore oil fuel connections are to be of closed type and suitably grounded during bunkering operations.

5.1.7 Air pipes shall discharge to a safe position and terminate with flame arresters in accordance with MSC/ Circ. 677.

■ *Section 6* Lubricating/hydraulic oil systems

6.1 Lubricating oil arrangements

6.1.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems in machinery spaces and, whenever practicable, in auxiliary machinery spaces are to comply with the provisions of 3.2 (except 3.2.2), 3.4 and 4.9 (except 4.9.3).

6.1.2 Tanks containing lubricating oil located within major fire hazard areas are to be of steel or other equivalent material.

6.1.3 Where lubricating oil tanks have a capacity of less than 0,5 m^3, consideration will be given to relaxing the requirements for remote controls to be fitted.

6.1.4 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submiited for consideration.

6.1.5 In addition, craft of 24 m or greater in length are to comply with the requirements of 4.5 to 4.7.

6.2 Arrangements for hydraulic and flammable oils

6.2.1 The requirements of this Section are applicable to flammable oils employed under pressure in power transmission, control, actuating and heating systems, and hydraulic media in systems which are providing essential services.

6.2.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed in the systems defined in this sub-Section are to comply with the provisions of 6.1.

6.3 Lubricating/hydraulic oil standby arrangements

6.3.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 500 kW.
(b) One main engine with its own pump is fitted and the output of the engine exceeds 500 kW.
(c) More than one engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 500 kW.

6.3.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use, except that where the conditions referred to in 6.3.1(c) apply, a complete spare pump may be accepted. In all cases, satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

6.3.3 Similar provisions to those of 6.3.1 and 6.3.2 are to be made where separate lubricating/hydraulic oil systems are employed for piston cooling, reduction gears, oil operated couplings controllable pitch propellers and steering systems etc., unless approved alternative arrangements are provided.

6.3.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

6.4 Lubricating oil contamination

6.4.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

6.4.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated rundown lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements are to be in accordance with the equipment manufacturer's procedures and recommendations.

6.4.3 The design and construction of engine and gear box piping arrangements are to prevent as far as practicable, contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where engines or gearboxes are partly installed below the lower platform.

6.4.4 Where a lubricating oil filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

6.4.5 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

■ *Section 7* Engine cooling water systems

7.1 General

7.1.1 The cooling arrangements provided are to be adequate to maintain all lubricating and hydraulic fluid temperatures within the manufacturer's recommended limits.

7.2 Main supply

7.2.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and essential auxiliary engines, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.3 Standby supply

7.3.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.3.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.
(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.
(c) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.
(d) Where each auxiliary engine is fitted with a cooling water pump, standby means of cooling need not be provided. Where, however, a group auxiliary engine is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system.

This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.4 Selection of standby pumps

7.4.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed. Where necessary, water boxes, etc., are to be protected against inadvertent over-pressure by an approved device.

7.5 Relief valves on main cooling water pumps

7.5.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

7.6 Sea inlets

7.6.1 Not less than two sea inlets are to be provided for the pumps supplying the sea water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.6.2 Where standby pumps are not connected ready for immediate use (*see* 7.3.2(b) and (d)), the main pump is to be connected to both sea inlets.

7.6.3 The auxiliary cooling water sea inlets are to be located one on each side of the craft.

7.7 Strainers

7.7.1 Where sea water is used for the direct cooling of the main engines and essential auxiliary engines, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

■ *Section 8* Miscellaneous machinery

8.1 General

8.1.1 Alarms and safeguards are indicated in Table 1.8.1.

Table 1.8.1 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	—
Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	—

Section 9
Special requirements for multi-hull craft

9.1 General

9.1.1 The requirements of Sections 1 to 8 are generally applicable to multi-hull craft except where these are modified by the requirements of this Section.

9.1.2 Where the machinery piping arrangements in each hull of a multi-hull craft are separate, the machinery piping and standby requirements for each hull are to be as detailed in 6.3.1(c) and 7.3.2(b), i.e. the requirements for a twin-engined mono-hull craft apply.

9.1.3 Where a multi-hull craft cannot navigate safely with the main propulsion machinery in one hull out of action, the machinery piping and standby requirements are to be as detailed in 6.3.1(a) or (b), and 7.3.2(a), i.e. the requirements for a single-engined mono-hull craft apply to the machinery in each hull.

Section 10
Requirements for Passenger (A) Craft

10.1 General

10.1.1 The requirements of Sections 1 to 9 apply except that the standby machinery arrangements detailed in Sections 6 and 7 are not required.

Section 11
Requirements for small craft which are not required to comply with the HSC Code

11.1 General

11.1.1 The requirements of this Section replace Sections 3.2 to 3.4 and 4, 5, 6 and 7 of this Chapter, *see also* Ch 1,15.

11.2 Oil fuel system

11.2.1 Where a power driven oil fuel transfer pump is fitted, it is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which the pump is situated, as well as from the compartment itself.

11.2.2 Where a power driven pump is necessary for transferring oil fuel, a standby pump is to be provided and connected ready for use.

11.3 Separate oil fuel tanks

11.3.1 Except for very small tanks separate oil fuel tanks are to be not less than 3 mm in thickness. The seams are to be welded or brazed. Steel tanks are to be protected from corrosion.

11.3.2 Before installation, all tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

11.3.3 Separate oil fuel tanks are to be securely fixed in position, and located as remote as practicable from exhaust manifolds and exhaust pipes or other hot surfaces and not above any electrical apparatus. Where this cannot be avoided, a drip tray is to be fitted under the tank and extended sufficiently to catch any drips from fittings attached to the tank.

11.3.4 Oil fuel tanks are not to be fitted above or adjacent to oil fired heaters, cooking stoves, equipment using naked flames or electrical equipment unless this is suitably constructed or enclosed.

11.4 Oil fuel filling

11.4.1 The filling pipe is to be of metallic construction and is to be a permanent fixture led from the deck and secured to the tank by an approved connection. A screwed cap and name plate inscribed ‘Oil Fuel’ is to be provided at the filling point.

11.4.2 Flexible hoses are not permitted as filling pipes. In wood or composite craft short lengths may be employed at the deck connection to accommodate any movement between the tank and the deck fitting.

11.5 Oil fuel supply

11.5.1 Provision is to be made for efficient filtration of the oil fuel supply to the engine.

11.6 Oil fuel valves and cocks

11.6.1 Outlet valves or cocks are to be fitted to all deep tanks. The valves are to be fitted directly to the tank plating and are to be capable of being closed locally and from positions which will always be readily accessible in the event of fire.

11.6.2 Valve covers are to be so constructed that they will not become slack when the valves are operated.

11.6.3 Heat sensitive materials are not to be used in the construction of valves and cocks.

11.6.4 Where drain cocks or valves are fitted to oil fuel tanks they are to be of the self-closing type and suitable provision is to be made for collecting the oil discharge.

11.7 Flexible hoses for oil fuel systems

11.7.1 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.8 Pipe joints for oil fuel systems

11.8.1 Where flanged joints are used the jointing material is to be impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.8.2 Soft solder is not to be used for attaching pipe fittings.

11.9 Engine cooling system

11.9.1 Where sea water is used for the direct cooling of the engine, an efficient strainer which can be cleared from inside the craft is to be fitted between the sea inlet valve and the pump.

11.9.2 Means are to be provided for cleaning the strainer without interruption to the cooling water supply, where necessary.

11.9.3 Means are to be provided for indicating the temperature of the engine cooling media.

11.9.4 Alarms for the engine cooling water system are to be provided in accordance with Part 10.

11.10 Lubricating oil system

11.10.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil.

11.10.2 Where necessary, flexible pipes of approved type may be used as short joining lengths to the engine.

11.10.3 In general, joints are to be of the flanged type with jointing materials which are impervious to oil. Cone type joints and approved types of compression fittings may be permitted for pipes having a bore not exceeding 40 mm.

11.10.4 Soft solder is not to be used for attaching pipe fittings.

11.10.5 Means are to be provided for indicating the lubricating oil pressure.

11.10.6 Alarms for the lubricating oil systems are to be provided in accordance with Part 10.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, where plans have to be submitted in accordance with 1.2.

1.1.2 Seamless pressure vessels are to be manufactured in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) where applicable.

1.1.3 Steam raising plant and associated pressure vessels should be designed and constructed in accordance with Pt 5, Ch 10 of the *Rules and Regulations for the Classification of Ships* (hereinafter referred to as the Rules for Ships).

1.2 Details to be submitted

1.2.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and
$pV > 600$
$p > 1$
$V > 100$
V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases for fire-fighting, or flammable liquids, and
$p > 7$
$V > 100$
V = volume (litres)
p = design pressure (bar).

1.3 Materials

1.3.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the Rules for Materials. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable National or International Standard. The manufacturer's certificate will be accepted in lieu of LR's material certificate for such materials.

1.3.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless and Class 1 and Class 2/1 fusion welded pressure vessels:
340 to 520 N/mm^2.

(b) For Class 2/2 and where required Class 3 fusion welded pressure vessels:
340 to 430 N/mm^2.

1.3.3 Where it is proposed to use materials other than those specified in the Rules for Materials, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.4 Classification of fusion welded pressure vessels

1.4.1 Fusion welded pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.4.2 Fusion welded pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar, or
(b) where the metal temperature exceeds 150°C, or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm exceeds 157, or
(d) where the shell thickness does not exceed 38 mm.

1.4.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5 Design pressure

1.5.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.6 Metal temperature

1.6.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.6.2 For fusion welded pressure vessels the minimum design temperature, T, is not to be less than 50°C.

1.7 Definition of symbols

1.7.1 The symbols used in the various formulae in Sections 2 to 6, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

p = design pressure, in bar, *see* 1.5
r_i = inside knuckle radius, in mm
r_o = outside knuckle radius, in mm
t = minimum thickness, in mm
D_i = inside diameter, in mm
D_o = outside diameter, in mm
J = joint factor applicable to welded seams
R_i = inside radius, in mm
R_o = outside radius, in mm
T = design temperature, in °C
σ = allowable stress, in N/mm^2, *see* 1.8.

1.7.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5}$$

$$\sigma = \frac{R_{20}}{2,7}$$

$$\sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T, for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used
R_{20} = specified minimum tensile strength at room temperature
S_R = average stress to produce rupture in 100 000 hours at temperature, T
T = metal temperature, *see* 1.6.

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in 1.8.2, using the appropriate values for cast steel.

1.8.4 Where steels castings, which have been tested in accordance with the Rules for Materials, are also subjected to non-destructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in 1.8.3. Particulars of the non-destructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in Sections 2 to 6, where applicable. Fusion welded pressure parts are to be made in accordance with Section 8.

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,6

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels and all classes of vessel for the production and storage of steam are also to be butt welds. Circumferential joints for Class 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Class 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching dished ends, *see* Fig. 4.6.1.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in this Chapter, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

Section 2
Cylindrical shells subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, *t*, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{10\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i and σ are defined in 1.7

J = the joint factor of the longitudinal joints (expressed as a fraction), *see* 1.9.1. In the case of seamless shells clear of openings, J = 1,0.

2.1.2 The formula in 2.1.1 is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than $1{,}5R_i$.

2.1.3 For fusion welded pressure vessels, *t*, is to be not less than $3 + \frac{D_i}{1500}$ mm,

where

D_i is as defined in 1.7.

2.1.4 The minimum thickness of vessels manufactured of corrosion resistant steels will be the subject of special consideration.

2.2 Unreinforced openings

2.2.1 The maximum diameter, *d*, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8{,}08\,[D_o\,t\,(1 - K)]^{1/3} \text{ in mm}$$

The value of K to be used is calculated from the following formula:

$$K = \frac{p\,D_o}{18{,}2\sigma\,t} \text{ but is not to be taken as greater than } 0{,}99$$

where

p, D_o and σ are as defined in 1.7

t = actual thickness of shell, in mm.

2.2.2 For elliptical or oval holes, *d*, for the purposes of 2.2.1, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.2.3 No unreinforced opening is to exceed 200 mm in diameter.

2.2.4 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$$d + 1{,}1\sqrt{D\,t} \quad \text{with a minimum } 5d$$

where

d = diameter of openings in shell (mean diameter if dissimilarly sized holes are involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

2.3 Reinforced openings

2.3.1 Openings larger than those permitted by 2.2 are to be compensated in accordance with Fig. 4.2.1(a) or (b). The following symbols are used in Fig. 4.2.1(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with 3.1 without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding D, in mm

$C = \sqrt{d_o\,t_b}$ in mm

$D = \sqrt{D_i\,t_a}$ and is not to exceed $0{,}5d_o$, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

NOTE

σ_p, σ_r and σ_w are not to be taken as greater than σ.

2.3.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in 2.3.1.

2.3.3 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

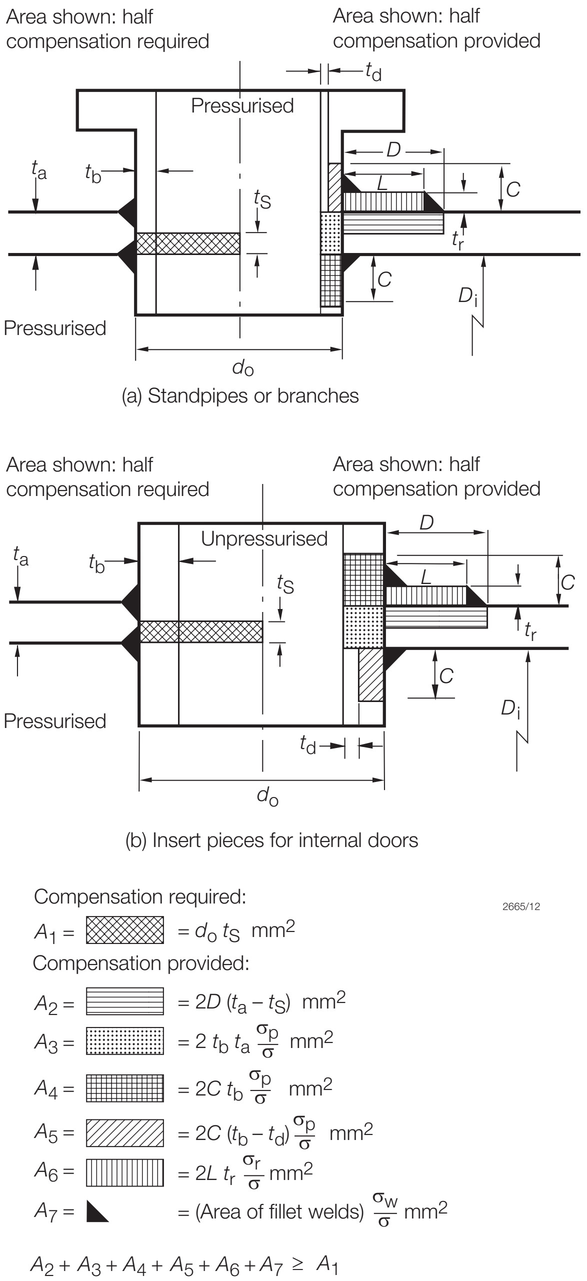


Fig. 4.2.1
Compensation for welded standpipes or branches in cylindrical shells

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, t, of a spherical shell is to be determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma\,J - 0{,}5p} + 0{,}75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

3.1.2 The formula in 3.1.1 is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in 3.1.1, t is to be not less than $\frac{D_i}{1500}$ + 3 mm for other pressure vessels, where D_i is as defined in 1.7.

3.1.4 The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.5 Openings in spherical shells requiring compensation are to comply, in general, with 2.3, using the calculated and actual thicknesses of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{p\,D_o\,K}{20\sigma\,J} + 0{,}75 \text{ mm}$$

where

t, p, D_o, σ and J are as defined in 1.7

K = a shape factor, *see* 4.2 and Fig. 4.4.1.

4.1.2 For semi-ellipsoidal ends:

the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

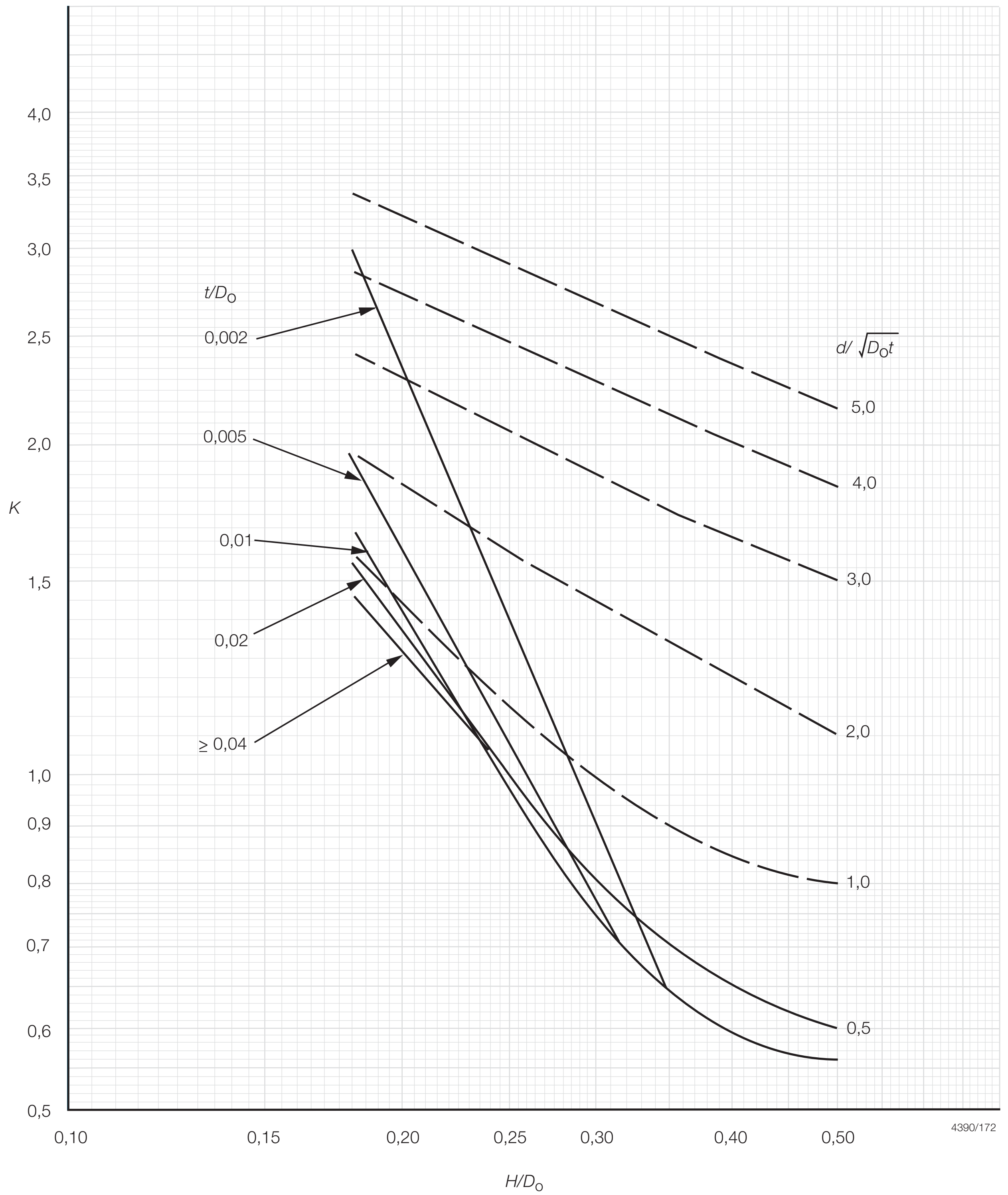


Fig. 4.4.1 Shape factor

4.1.3 For torispherical ends:

- the internal radius, $R_i \leq D_o$
- the internal knuckle radius, $r_i \geq 0,1D_o$
- the internal knuckle radius, $r_i \geq 3t$
- the external height, $H \geq 0,18D_o$ and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0,5D_o)(R_o + 0,5D_o - 2r_o)}$$

4.1.4 In addition to the formula in 4.1.1 the thickness, t, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{p\,R_i}{20\sigma J - 0,5p} + 0,75 \text{ mm}$$

where

t, p, R_i, σ and J are as defined in 1.7.

4.1.5 The thickness required by 4.1.1 for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0,5\sqrt{R_i t}$ mm, before reducing to the crown thickness permitted by 4.1.4,

where

t = the required thickness from 4.1.1.

4.1.6 In all cases, H, is to be measured from the commencement of curvature, *see* Fig. 4.4.2.

4.1.7 For fusion welded pressure vessels the minimum thickness of the head, t, is to be not less than $3 + \frac{D_i}{1500}$ mm

where

D_i is as defined in 1.7.

4.1.8 For ends which are butt welded to the shell the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by 2.1.

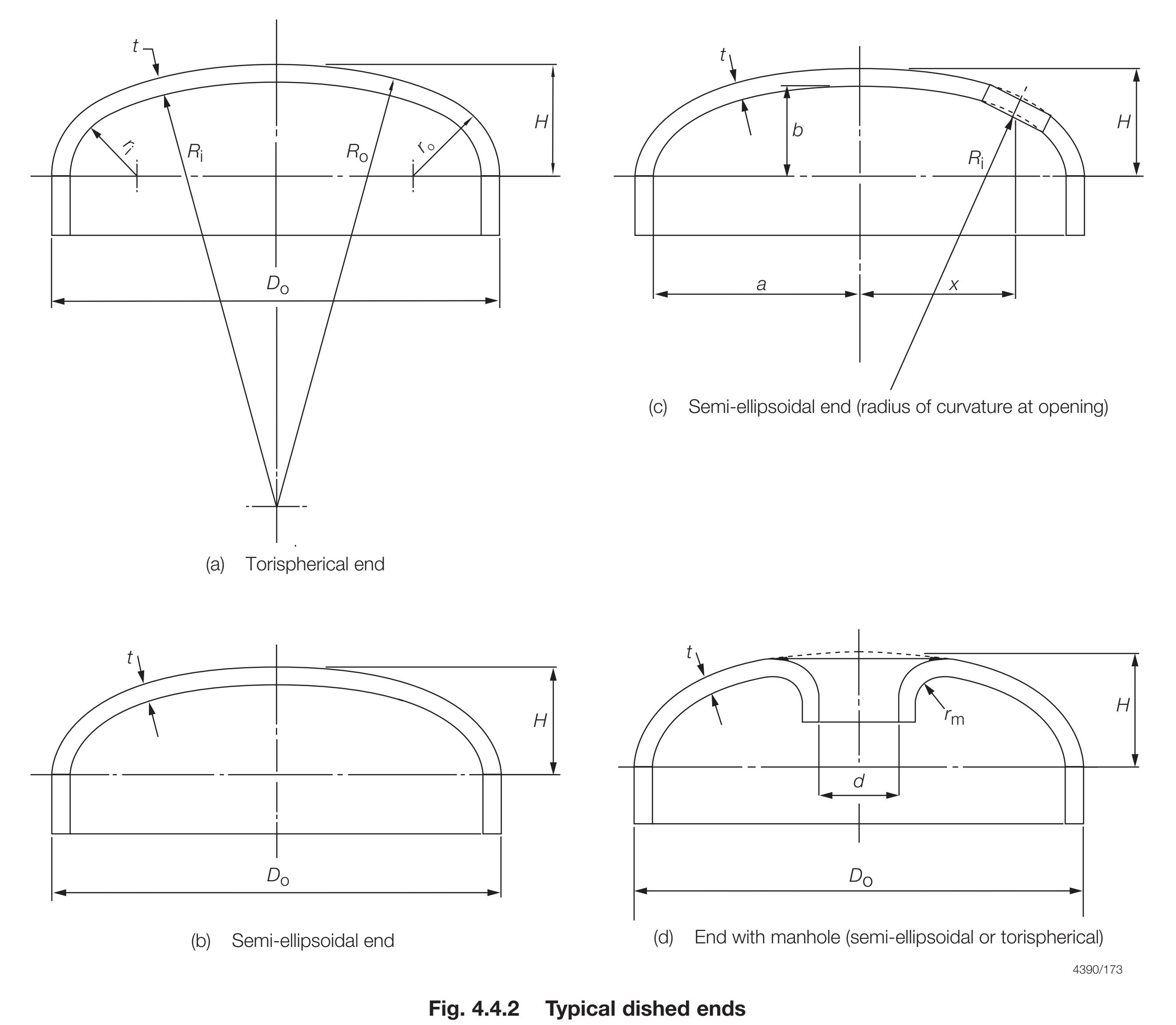


Fig. 4.4.2 Typical dished ends

4.2 Shape factors for dished ends

4.2.1 The shape factor, K, to be used in 4.1.1 is to be obtained from the curves in Fig. 4.4.1, and depends on the ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, K, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{t}{D_o}$, aswell as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of K.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in Fig. 4.4.1 provide values of K, to be used in 4.1.1, for ends with unreinforced openings. The selection of the correct curve depends on the value of $\frac{d}{\sqrt{D_o t}}$ and a trial calculation is necessary to select the correct curve,

where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_o} \leq 0{,}1$$

$$\frac{d}{D_o} \leq 0{,}7$$

4.3.4 From Fig. 4.4.1 for any selected ratio of $\frac{H}{D_o}$ the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for K. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in 4.3 apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m of the flanging is to be not less than 25 mm, *see* Fig. 4.4.2(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in Fig. 4.4.3.

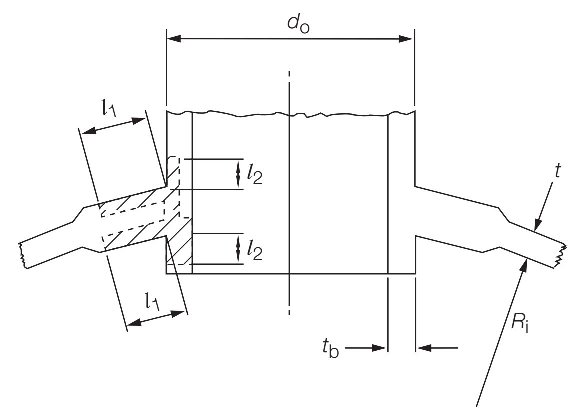


Fig. 4.4.3 Limits for reinforcement

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by 4.3, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see* Fig. 4.4.4. Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i t}$ or $0{,}5d_o$ whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

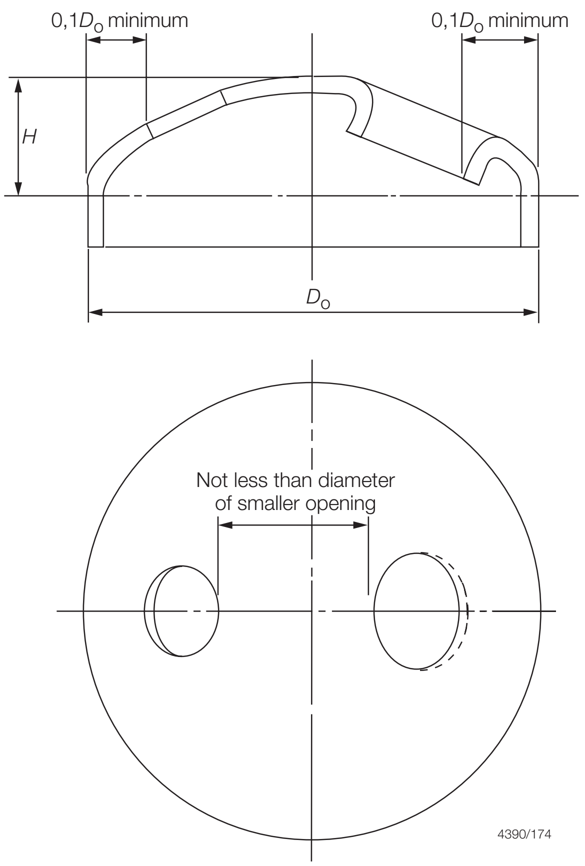


Fig. 4.4.4 Opening in dished ends

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

$$\frac{\left[a^4 - x^2\left(a^2 - b^2\right)\right]^{3/2}}{a^4\, b}$$

where

a, b and x are shown in Fig. 4.4.2(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in Fig. 4.4.3

t_b = actual thickness of ring or standpipe, in mm.

4.6.3 The shape factor, K, for a dished end having a reinforced opening can be read from Fig. 4.4.1 using the value obtained from:

$$\frac{d_o - \dfrac{A}{t}}{\sqrt{D_o\, t}} \text{ instead of from } \frac{d}{\sqrt{D_o\, t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on Fig. 4.4.3

As in 4.3, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in Fig. 4.4.3 is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1, plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2, plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2, and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with 5.1.

4.6.5 If the material of the ring or the reinforcing plates has an allowable stress value lower than that of the end plate, then the effective cross-sectional area, A, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of 4.6 are to be applied.

■ *Section 5* Standpipes and branches

5.1 Minimum thickness

5.1.1 The minimum wall thickness, t, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{p\, D_o}{20\sigma + p} + 0{,}75 \text{ mm}$$

$$t = 0{,}015 D_o + 3{,}2 \text{ mm}$$

where

t, p, D_o and σ are defined in 1.7.

If the second formula applies, the thickness need only be maintained for a length, L, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3{,}5\sqrt{D_o\, t} \text{ mm}$$

5.1.2 In no case does the wall thickness need to exceed that of the shell as required by 2.1, 3.1 or 4.1 as applicable.

Section 6 Unstayed circular flat end plates

6.1 Minimum thickness

6.1.1 Ends attached by welding are to be designed such that the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_i \sqrt{\frac{pC}{\sigma}} + 0{,}75 \text{ mm}$$

where

p and σ are as defined in 1.7.

t = minimum thickness of end plate, in mm

d_i = internal diameter of circular shell, in mm

C = a constant depending on method of end attachment, *see* Fig. 4.6.1

(a) For end plates welded as shown in Fig. 4.6.1(a):
C = 0,019 for circular shells.

(b) For end plates welded as shown in Figs. 4.6.1(b) and (c):
C = 0,028 for circular shells.

6.1.2 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

6.1.3 Openings in flat plates are to be compensated in accordance with Fig. 4.2.1(a) or (b) with the value of A_1, the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2{,}4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with 6.1.1, as applicable, without corrosion allowance

Limit D = $0{,}5d_o$.

Section 7 Construction

7.1 Access arrangements

7.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

7.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

7.1.3 Doors for manholes and sightholes are to be formed from the steel plate or of other approved construction, and all jointing surfaces are to be machined.

7.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

7.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

7.1.6 The crossbars or dogs for doors are to be of steel.

7.1.7 External circular flat cover plates are to be in accordance with a recognised standard.

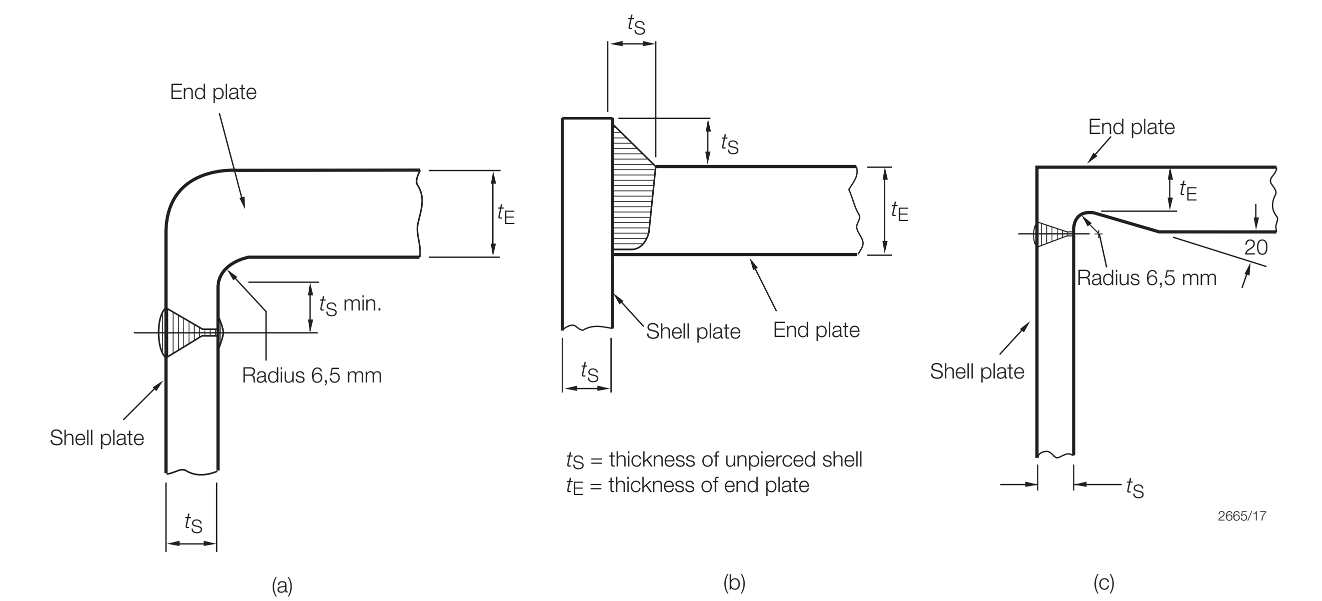


Fig. 4.6.1 Typical methods of attachment of unstayed circular flat end plates

7.2 Torispherical and semi-ellipsoidal ends

7.2.1 For typically acceptable types of attachment for dished ends to cylindrical shells, *see* Fig. 4.7.1. Types (d) and (e) are to be made a tight fit in the cylindrical shell.

7.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

7.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see* 2.1.

7.3 Welded-on flanges, butt welded joints and fabricated branch pieces

7.3.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

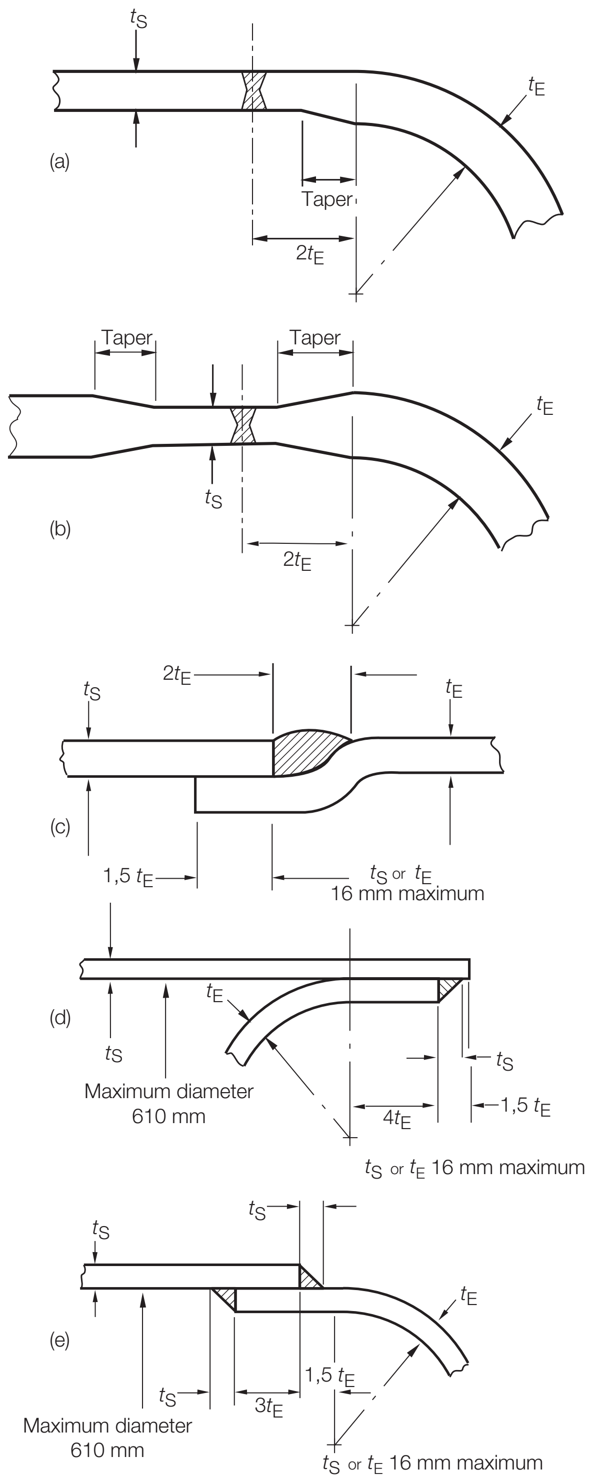
7.3.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

7.3.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised standards will be accepted.

7.3.4 Typical examples of welded-on flange connections are shown in Fig. 4.7.2(a) to (f), and limiting design conditions for the flange types are shown in Table 4.7.1. In Fig. 4.7.2, *t* is the minimum Rule thickness of the standpipe or branch.

7.3.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

7.3.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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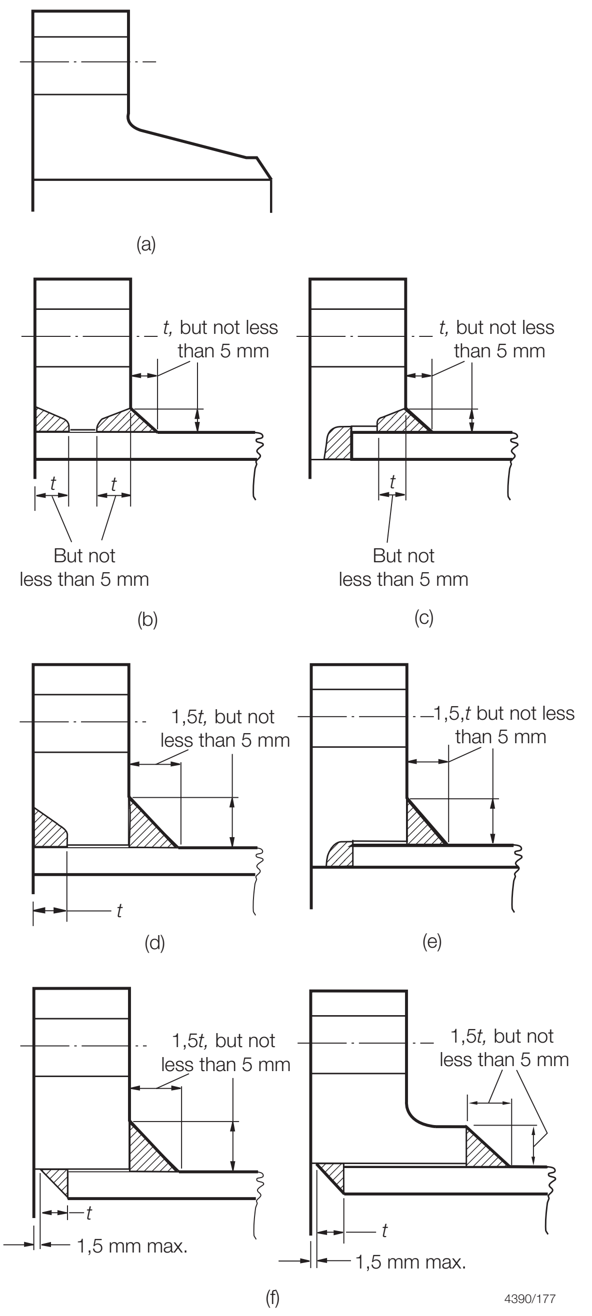
Fig. 4.7.1
Typical attachment of dished ends to cylindrical shell



'*t*' is the minimum Rule thickness of standpipe or branch

Fig. 4.7.2
Typical example of welded flange connections

7.3.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick.

7.3.8 Threaded sleeve joints complying with Ch 1,5.5.1 may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

7.3.9 Socket weld joints are not to be used where fatigue, severe erosion, crevice corrosion or stress corrosion are expected to occur, for example, blow down, drain, scum and chemical dosing connections.

7.4 Welded attachments to pressure vessels

7.4.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as a means of indicating any leakage during hydraulic testing and in service.

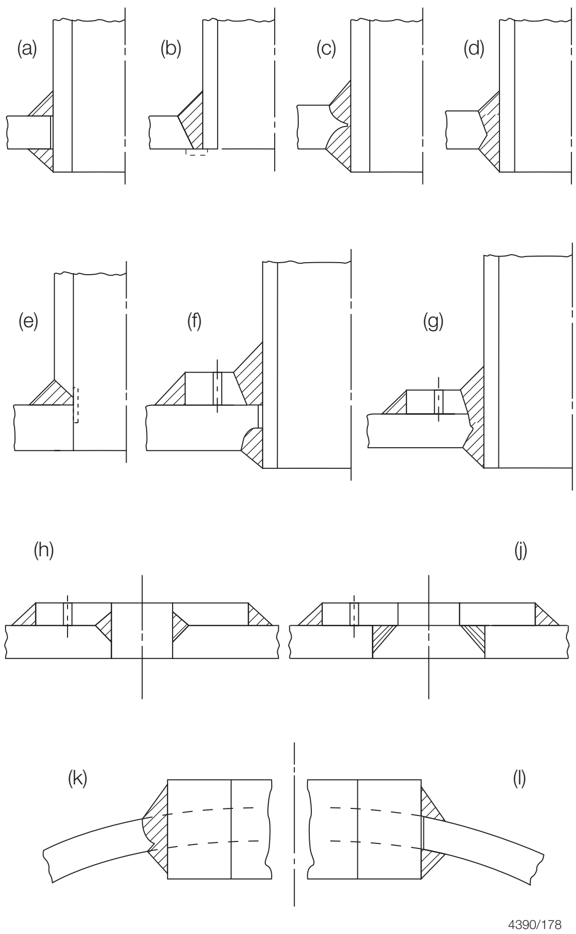
7.4.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see* Fig. 4.7.3. Alternative methods of attachment may be accepted provided details are submitted for consideration.

7.4.3 Where fillet welds are used to attach standpipes, there are to be equal sized welds both inside and outside the vessel shell, *see* Fig. 4.7.3(a) and (l). The leg length of each of the fillet welds is to be not less than the actual thickness of the thinner of the parts being joined.

Table 4.7.1 Limiting design conditions for flanges

Flange type	Maximum pressure	Maximum temperature	Maximum pipe o.d.	Minimum pipe bore
		°C	mm	mm
(a)	Pressure temperature ratings to be in accordance with a recognised Standard	No restriction	No restriction	No restriction
(b)		No restriction	168,3 for alloy steels*	No restriction
(c)		No restriction	168,3 for alloy steels*	75
(d)		425	No restriction	No restriction
(e)		425	No restriction	75
(f)		425	No restriction	No restriction

NOTE
* No restriction for carbon steels



Type (a) and (l) attachments are not to be used for openings which require to be compensated. Backing rings may be used with types (b) and (e).

Fig. 4.7.3
Typical acceptable methods of attaching branches and pads

Section 8 Requirements for fusion welded pressure vessels

8.1 General requirements

8.1.1 Welded construction of pressure vessels is to be in accordance with the requirements specified in Ch 13,1 and 4 of the Rules for Materials.

8.1.2 Fusion welded pressure vessels constructed to Class 1 and Class 2/1 requirements will be accepted only if manufactured by firms equipped and competent to undertake high quality welding. In order that firms may be approved for this purpose, it will be necessary for the Surveyors to visit the works for the purpose of inspecting the welding plant equipment and procedures, and to arrange for the carrying out of preliminary tests as stated in Ch 13,4 of the Rules for Materials.

Section 9 Mountings and fittings for pressure vessels

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also* 9.2.3 and 9.2.4.

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

■ *Section 10* Hydraulic tests

10.1 Fusion welded pressure vessels

10.1.1 Fusion welded pressure vessels are to be tested on completion to a pressure, p_T, determined by the following formula, without showing signs of weakness or defect:

$$p_T = 1{,}3 \frac{\sigma_{50}}{\sigma_t} \frac{t}{(t - 0{,}75)} p$$

but in no case is to exceed

$$1{,}5 \frac{t}{(t - 0{,}75)} p$$

where

p = design pressure, in bar
p_T = test pressure, in bar
t = nominal thickness of shell as indicated on the plan, in mm
σ_T = allowable stress at design temperature, in N/mm^2
σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 11* Fibre reinforced plastics pressure vessels

11.1 General

11.1.1 Pressure vessels may be constructed in fibre reinforced plastics provided the manufacturer is competent and suitably equipped for this purpose.

11.1.2 Pressure vessels are to be of standard design whose suitability has been established by fatigue and burst tests on a prototype.

11.2 Prototype testing

11.2.1 For the fatigue test the pressure shall be cycled from atmospheric to design pressure 100 000 times at the design temperature.

11.2.2 For the burst test the minimum bursting pressure shall be six times the design pressure.

11.3 Production hydraulic test

11.3.1 Vessels subject to internal pressure shall be hydraulically tested to not less than 1,5 times the design pressure.

■ *Section 12* Requirements for craft which are not required to comply with the HSC Code

12.1 Fibre reinforced plastics pressure vessels

12.1.1 Fibre reinforced plastics pressure vessels, where the product of the design pressure in bar and volume in litres exceeds 600, are not to be situated in machinery spaces or high risk areas on yachts and service craft less than 24 m.

12.1.2 Small fibre reinforced plastics pressure vessels will receive special consideration in relation to their intended duty and service conditions.

Rules and Regulations for the Classification of Special Service Craft

Volume 7

Part 16

Control and Electrical Engineering

July 2012

Lloyd's Register

LIFE MATTERS

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■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter applies to control engineering systems on special service craft.

1.1.2 Section 2 states requirements for alarm systems, safety systems and automatic or remote controls where fitted.

1.1.3 Section 4 states requirements which shall apply where it is intended to operate the craft with machinery spaces unattended. In general, craft complying with the requirements of Section 4 will be eligible for the class notation **UMS**.

1.1.4 Section 5 states requirements which shall apply where it is intended to operate the craft with machinery spaces under continuous supervision from a centralised control station. In general, craft complying with the requirements of Section 5 will be eligible for the class notation **CCS**.

1.1.5 Lloyd's Register (hereinafter referred to as 'LR') will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans and information

1.2.1 Plans and information as detailed in 1.2.2 to 1.2.7 are to be submitted in triplicate.

1.2.2 A description of operation with explanatory diagrams together with line diagrams of control circuits, list of monitored, control and alarm points is required for the following machinery or equipment:

- Fixed water-based local application fire-fighting systems, *see* 2.9.
- Air compressors.
- Bilge systems.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.
- Thrust units.
- Valve position indicating systems.
- Waterjets for propulsion purposes.
- Windlasses.

1.2.3 **Test schedules** (for both works testing and sea trials), which should include methods of testing and test facilities, *see* 7.4.1.

1.2.4 **Alarm systems**. Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation. Details of alarms and warnings presented by the user interface including: an approach to category assignment which is in accordance with the IMO *Code on Alerts and Indicators, 2009*; and for alarms required by these Rules, the intended operator response and the message is to be presented.

1.2.5 **Programmable electronic systems**. In addition to the documentation required by 1.2.2, the following is to be submitted:

(a) System requirements specification.
(b) System integration plan, *see* 2.14.2.
(c) Failure Mode and Effects Analysis (FMEA), *see* 2.14.5.
(d) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(e) Hardware certification details, *see* 2.10.5 and 2.13.3.
(f) Software quality plans, including applicable procedures, *see* 2.10.25.
(g) Factory acceptance, integration and sea trial test schedules for hardware and software.
(h) Details of data storage arrangements, *see* 2.10.10 and 2.13.6.

1.2.6 For wireless data communication equipment:

(a) Details of manufacturer's installation and maintenance recommendations;
(b) network plan with arrangement and type of aerials and identification of location;
(c) specification of wireless communication system protocols and management functions, *see* 2.12.4; and
(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

1.2.7 **Control station**. Plans showing the location and details of control stations, e.g., control panels and consoles. Location and details of controls and displays on each panel. Details of user interface specifications. A general arrangement plan of control rooms showing the position of consoles, handrails, operator area, lighting, door and window arrangements. Drawing of HVAC systems including vent arrangements.

1.2.8 **Fire detection systems**. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.2.9 **Cables**. For details of instrumentation and control system cabling requirements, *see* Ch 2,11.

1.3 Control, alarm and safety equipment

1.3.1 Major units of equipment associated with control, alarm and safety systems as defined in 1.2 are to be surveyed at the manufacturers' works and the inspection and testing is to be to the Surveyor's satisfaction, *see also* 1.2.2.

1.3.2 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the *List of Lloyd's Register Type Approved Products* published by LR.

1.3.3 Where equipment requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal air conditioning system. Failure of the air conditioning system is to initiate an alarm.

1.3.4 Assessment of performance parameters, such as accuracy, repeatability, etc., are to be in accordance with an acceptable National or International Standard, e.g., IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories*.

1.4 Alterations and additions

1.4.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.4.2 Details of proposed software modifications are to be submitted for consideration. Where the modification may affect compliance with these Rules, proposals for verification and validation are also to be submitted.

1.4.3 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

■ *Section 2*
Essential features for control, alarm and safety systems

2.1 General

2.1.1 Where it is proposed to install control, alarm and safety systems to the machinery and equipment listed in 1.2.2 the applicable features contained in this Section are to be incorporated in the system design.

2.1.2 Systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications*, may be accepted as meeting the requirements of this Section in which case evidence of compliance is to be submitted for consideration.

2.2 Control stations for machinery

2.2.1 A system of alarm and warning displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment by duty personnel. This may be provided at a main control station or, alternatively at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault condition.

2.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of two way voice communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

2.2.3 Where operator interfaces are installed in the wheelhouse, illumination should not interfere with night vision. All illumination and lighting of instruments, keyboards and controls are to be adjustable to zero illumination, except for lighting for visual indication of alarms and the controls of dimmers, which are to remain readable.

2.2.4 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

2.2.5 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

2.2.6 Control of machinery and associated equipment is to be possible only from one station at a time.

2.2.7 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

2.2.8 For additional requirements where control stations incorporate visual display units and keyboard input facilities, *see* 2.10.

2.3 Alarm systems

2.3.1 Where an alarm system, which will alert relevant personnel to faults, abnormal situations and other conditions requiring attention in the machinery and the safety and control systems required by this Chapter or other Sections of the Rules, is to be installed, the requirements of 2.3.2 to 2.3.20 are to be satisfied.

2.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

2.3.3 Alarms and warnings associated with machinery and equipment required to satisfy this sub-Section are to be categorised according to the urgency and type of response required by the crew, as described in the IMO *Code on Alerts and Indicators, 2009*. The assignment of the category to each alert is to be evaluated on the basis not only of the machinery or equipment being monitored, but also the complete installation. Categories not included in an alarm system may be omitted from the system design. Details of alternative alert management proposals supported with evidence of service experience, may be submitted for consideration by LR.

2.3.4 Where the facility to provide messages in association with alarms and warnings exists, messages accompanying alarms and warnings are to describe the condition and indicate the intended response required by the crew.

2.3.5 Where the facility to provide messages in association with alarms and warnings exists, messages of different categories are to be clearly distinguishable from each other.

2.3.6 Where alarms are displayed as group alarms, provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

2.3.7 All alarms are to be both audible and visual. If arrangements are made to silence audible signals they are not to extinguish visual indications.

2.3.8 Acknowledgement of visual alarms is to be clearly indicated.

2.3.9 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible signal or extinguish the visual indication in that machinery space.

2.3.10 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible signals and visual indications are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm in the control room then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be reinitiated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

2.3.11 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

2.3.12 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

2.3.13 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

2.3.14 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

2.3.15 The alarm system is to be capable of being tested during normal machinery operation, *see* 7.1.2.

2.3.16 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

2.3.17 Disconnection or manual overriding of any part of the alarm system is to be clearly indicated.

2.3.18 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.3.19 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

2.3.20 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring shutdown or slowdown action are to be given visual prominence.

2.4 Safety systems, general requirements

2.4.1 Where safety systems are provided, the requirements of 2.4.2 to 2.4.12 are to be satisfied. The requirements of this sub-Section apply, where relevant, to the safety systems installed on the equipment defined in 1.2.3, including those provided in addition to those safeguards required by other Sections of the Rules.

2.4.2 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g., by the starting of standby machinery, or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g., by reducing the output of the machinery, or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

2.4.3 The safety system required by 2.4.2(c) is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

2.4.4 For safety systems required by 2.4.2(a) and (b) complete independence from other control systems is not necessary.

2.4.5 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

2.4.6 The safety system is to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation.

2.4.7 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

2.4.8 The safety system is to be manually reset before the relevant machinery can be restarted.

2.4.9 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. High speed craft are to be provided with arrangements for overriding automatic shutdown systems except in cases where there is a risk of complete breakdown or explosion.

2.4.10 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

2.4.11 Failure of any power supply to a safety system is to operate an audible and visual alarm.

2.4.12 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

2.5 Control systems

2.5.1 Where control systems are provided, the requirements of 2.5.2 to 2.5.11 are to be satisfied.

2.5.2 Control systems for machinery operations are to be stable throughout their operating range.

2.5.3 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

2.5.4 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

2.5.5 Control systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

2.5.6 Failure of any power supply to a control system is to operate an audible and visual alarm.

2.5.7 Where machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with the alarms and safety arrangements required by the appropriate Chapter(s). Alternative arrangements which provide equivalent safeguards will be considered.

2.5.8 Remote or automatic controls are to be provided with sufficient instrumentation at the relevant control stations to ensure effective control by duty personnel and to indicate that the system is functioning correctly.

2.5.9 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could hazard the machinery.

2.5.10 Where machinery, controlled in accordance with 2.5.7, is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

2.5.11 Failure of a control system is not to result in the loss of ability to provide essential services by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also* 2.13.2. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery by duty personnel.

2.6 Bridge control for propulsion machinery

2.6.1 Where a bridge control system for propulsion machinery is to be fitted, the requirements of 2.6.2 to 2.6.8 are to be satisfied.

2.6.2 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

2.6.3 Two independent means are to be provided on the bridge to enable the watchkeeper to stop the propulsion machinery in an emergency.

2.6.4 Audible and visual alarms are to operate on the bridge and in the machinery alarm system if any power supply to the bridge control system fails. Where practicable the preset speed and direction of thrust are to be maintained until corrective action is taken.

2.6.5 Cargo (B) high speed craft are to be provided with a standby system for controlling propulsion machinery. A standby system controllable from an engine control space such as an engine control room outside the bridge is acceptable.

2.6.6 Passenger (B) high speed craft are to be provided with a standby system for controlling propulsion machinery from the bridge.

2.6.7 Passenger (B) high speed craft are to be provided with additional control of propulsion and manoeuvring at the same location as the emergency functions referred to in Ch 2,16.6.12. Such stations are to have direct communication with the bridge area.

2.6.8 For high speed craft, failure of the operating propulsion control system or of transfer of control is to bring the craft to low speed without hazarding passengers or craft.

2.7 Valve control systems

2.7.1 Where cargo, bilge, ballast, oil fuel transfer and sea valves for engine services are operated by remote or automatic control, the requirements of 2.7.2 to 2.7.5 are to be satisfied.

2.7.2 Failure of actuator power is not to permit a valve to move to an unsafe condition.

2.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

2.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

2.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

2.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see* Pt 3, Ch 4,9.4. For power supplies on passenger craft, *see* Ch 2,3.2.

2.8 Fire detection alarm systems

2.8.1 Where an automatic fire detection system is to be fitted in a machinery space the requirements of 2.8.2 to 2.8.14 are to be satisfied.

2.8.2 A fire detection control unit is to be located in the navigating bridge area, the fire control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

2.8.3 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be so located that it is easily accessible to responsible members of the crew at all times. An indicating panel is to be located on the navigating bridge, together with TV monitoring in the case of high speed craft.

2.8.4 An audible fire-alarm signal is to be provided having a characteristic which distinguishes it from the alarm signal required by 2.3 or any other alarm system. The audible fire-alarm signal is to be immediately audible on all parts of the navigating bridge, at the fire control station and the machinery control stations, and throughout the crew accommodation areas and the machinery spaces.

2.8.5 Facilities are to be provided in the fire detection system to manually initiate the fire alarm from the following locations:
(a) Positions adjacent to all exits from machinery spaces.
(b) Navigating bridge.
(c) Control station in engine room.
(d) Fire control station.

2.8.6 The alarm system is to be designed with self-monitoring properties and system failures are to initiate an audible and visual alarm distinguishable from the fire alarm signal. This alarm may be incorporated in the machinery alarm system.

2.8.7 Power supplies for the alarm system are to be in accordance with Ch 2,17.1.

2.8.8 Fire detection control units (including addressable systems), indicating panels, detector heads, manual call points and short circuit isolation units are to be Type Approved in accordance with the LR *Type Approval System*. For addressable systems, *see also* 2.10.

2.8.9 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided in order that the system will react to all possible fire characteristics.

2.8.10 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

2.8.11 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

2.8.12 When it is intended that a particular detector(s) is (are) to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

2.8.13 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire control panel for functional testing and reset of the system.

2.8.14 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective at sea and in port.

2.9 Fixed water-based local application fire-fighting systems

2.9.1 Where fixed water-based local application fire-fighting systems are required to be installed by National Administration requirements, arrangements are to be in accordance with this sub-Section.

2.9.2 Systems are to be available for immediate use and arranged for manual activation from inside and outside the protected space. *See also* Ch 2,16.3.4.

2.9.3 Activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the craft and is not to require confirmation of space evacuation or sealing, *see also* Ch 2,17.3.12.

2.9.4 System zones and protected areas are to be arranged to allow essential services to be provided by machinery and/or equipment located outside areas affected by direct spray or extended water in the event of a system activation, where the machinery and/or equipment is duplicated or otherwise replicated to provide redundancy.

2.9.5 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and initiation of alarms and warnings and processing information from detectors. This panel is to be independent of the fire detection control unit required by 2.8.

2.9.6 Alarms are to be initiated upon activation of a system and are to indicate the specific zone released at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible alarm is to be distinguishable from other safety system alarms.

2.9.7 A failure in a manual system activation switch circuit is not to prevent system activation using other installed manual system activation switches or, where installed, automatic activation. The means of activation are to be provided with self-monitoring facilities which will activate an alarm at an attended control station in the event of failure detection.

2.9.8 Where, additionally, the system is required to be capable of automatic release, the arrangements are to be in accordance with 2.9.8 to 2.9.12.

2.9.9 A minimum of two fire detectors are to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm at an attended control stationand is not to inhibit activation of the system under the control of the other detector or manually.

2.9.10 The fire detectors are to be arranged (located, oriented, guarded, etc.) to ensure that a fire in one protected area will not result in the inadvertent automatic activation of a system for another protected area. Guards or barriers provided to comply with this requirement are not to reduce the ability to detect a fire in the protected area.

2.9.11 A fire detection alarm system panel in accordance with 2.8 may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by 2.9.5 for processing and action.

2.9.12 The system's fire detection systems and control units are to meet the performance criteria stipulated by the National Administration and are to be Type Approved in accordance with *Test Specification Number 1* given in LR's Type Approval System for an environmental category appropriate for the locations in which they are intended to operate.

2.10 Programmable electronic systems – General requirements

2.10.1 The requirements of this sub-Section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Systems for essential services and safety critical applications, systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of 2.11, 2.13 and 2.14, as applicable. For systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications, see* 2.1.2.

2.10.2 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of 2.10 to 2.14 related to providing those required functions.

2.10.3 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

2.10.4 In the event of failure of any programmable electronic equipment, the system and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

2.10.5 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also* 2.13.3.

2.10.6 Emergency stops are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of 2.13.2 and/or 2.13.9.

2.10.7 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2. Hardware failures indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

2.10.8 Means are to be provided to recover or replace data required for safe and effective system operation lost as a result of component failure. The submission required by 1.2.5 is to address reinstatement of system operation following data loss.

2.10.9 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply. For essential services and safety critical systems, *see* 2.13.6.

2.10.10 Where it is necessary to store data required for system operation in volatile memory, a back-up power supply is to be provided that prevents data loss in the event of loss of the normal power supply. The submission required by 1.2.5 is to include details of any routine maintenance necessary and the measures necessary to restore system operation in the event of data loss as a result of power supply failure.

2.10.11 Back-up power supplies required by 2.10.10 are to be rated to supply the connected load for a defined period of time that allows sufficient time to restore the supply in the event of loss of the normal power supply as a result of failure of a main source of electrical power. This period is not to be less than 30 minutes.

2.10.12 Where regular battery replacement is required to maintain the availability of volatile memory back-up power supply required by 2.10.10, these are to be included in the schedule of batteries required by Ch 2,1.2.10 and 12.7, irrespective of battery type and size. Applicable entries in this schedule are to note that these batteries are not for safety critical systems or essential or emergency services.

2.10.13 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration.

2.10.14 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

2.10.15 Displays and controls are to be protected against liquid ingress due to spillage.

2.10.16 Display units are to comply with the requirements of an acceptable National or International Standard e.g., IEC 60950:2005, *Safety of information technology equipment,* in respect of emission of ionising radiation.

2.10.17 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

2.10.18 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

2.10.19 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation in the event of failure of any unit or any power supply.

2.10.20 Software lifecycle activities, e.g., design, develop-ment, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2004, *Software engineering – Guidelines for the application of ISO 9001:2000 to computer software*, or equivalent, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

2.11 Data communication links

2.11.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of 2.11.2 to 2.11.10 are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

2.11.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for essential services. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

2.11.3 Loss of a data communication link is not to result in the loss of ability to operate any essential service by alternative means, *see also* 2.13.2.

2.11.4 The properties of the data communication link, (e.g., bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

2.11.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

2.11.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of 2.3 and, where applicable, 4.2 in the event of a failure of an active or standby component.

2.11.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also* 2.5.5.

2.11.8 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

2.11.9 Data cables are to comply with the applicable requirements of Ch 2,11. Other media will be subject to special consideration.

2.11.10 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

2.11.11 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

2.12 Additional requirements for wireless data communication links

2.12.1 The requirements of this sub-Section are in addition to 2.11 and apply to systems incorporating wireless data communication links.

2.12.2 Wireless data communication links are not to be used for safety critical systems or essential services that are required for the propulsion or safety of the craft, except as permitted by 2.12.3.

2.12.3 For services not required to operate continuously, wireless data communication links may be considered where an alternative means of operation that can be brought into action within an acceptable period of time is provided.

2.12.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:
(a) Message integrity: fault prevention, detection, diagnosis and correction, ensuring that the received message is not corrupted or altered when compared to the transmitted message.
(b) Configuration and device authentication: is to permit connection only of devices that are included in the system design.
(c) Message encryption: protection of the confidentiality and/or criticality of the data content.
(d) Security management: protection of network assets and prevention of unauthorised access to network assets.

2.12.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the craft is registered.

2.12.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner and Operator.

2.13 Programmable electronic systems – Additional requirements for essential services and safety critical systems

2.13.1 The requirements of 2.13.2 to 2.13.10 are to be complied with where control, alarm or safety systems for essential services, as defined by Ch 2,1.6, or safety critical systems, incorporate programmable electronic equipment:
(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards (e.g., fire, explosion, etc.), or to prevent mechanical damage which may result in the loss of an essential service (e.g., main engine low lubricating oil pressure shutdown).
(b) Applications that are not essential services may also be considered to be safety critical (e.g., domestic boiler low water level shutdown).

2.13.2 Alternative means of safe and effective operation are to be provided for essential services and, wherever practicable, these are to be by provision of a fully independent hard wired back-up system. Where these alternative means are not independent of any programmable electronic equipment, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

2.13.3 Items of programmable electronic equipment used to implement control, alarm and safety functions are to satisfy the requirements of LR's *Type Approval System Test Specification Number 1* (2002).

2.13.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

2.13.5 For essential services, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

2.13.6 Volatile memory is not to be used to store data required for:
- an essential service or safety critical functions; or
- ensuring safety or preventing damage, including during start-up or re-start.

Alternative proposals which demonstrates that an equivalent level of system integrity will be achieved may be submitted for consideration.

2.13.7 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of 2.3 and, where applicable, 4.2.

2.13.8 Where it is intended that the programmable electronic system implements emergency stop or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g., fully independent hard wired back-up system, redundancy with design diversity, etc.

2.13.9 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

2.13.10 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

2.14 Programmable electronic systems – Additional requirements for integrated systems

2.14.1 The requirements of 2.14.2 to 2.14.7 apply to integrated systems providing control, alarm or safety functions in accordance with the Rules, including systems capable of independent operation interconnected to provide co-ordinated functions or common user interfaces. Examples include integrated machinery control, alarm and monitoring systems, power management systems and safety management systems providing a grouping of fire, passenger, crew or craft safety functions, *see* Ch 2,17 to 19.

2.14.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements of all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for essential services or safety functions including fire, passenger, crew, and craft safety.

2.14.3 The system requirements specification, *see* 1.2.5, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

2.14.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

2.14.5 Where the integration involves control functions for essential services or safety functions, including fire, passenger, crew and craft safety, a Failure Mode and Effects Analysis (FMEA) is to be carried out in accordance with IEC 60812, or an equivalent and acceptable National or International Standard and the report and worksheets submitted for consideration. The FMEA is to demonstrate that the integrated system will 'fail-safe', *see* 2.4.6 and 2.5.5, and that essential services in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

2.14.6 The quantity and quality of information presented to the operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

2.14.7 Where information is required by the Rules or by National Administration requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also* 2.10.23 and 2.10.24.

■ *Section 3*
Ergonomics of control stations

3.1 Objectives

3.1.1 In order to take account of operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in 3.2.

3.1.2 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst operators at main control stations, the requirements of 3.3 are to be complied with.

3.1.3 The requirements of 3.4 to 3.6 apply to operator interfaces for essential engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

3.2 Control station layout

3.2.1 Control stations are to provide sufficient space and access for the intended number of operators in the expected operating conditions.

3.2.2 Local control stations are to be positioned to minimise the risk of harm to the operator.

3.2.3 Controls, displays and indicators are to be both logically and physically grouped according to their function.

3.2.4 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

3.2.5 Frequently used controls and displays are to be within easy reach and visible to the operator from the normal working position.

3.2.6 Controls and displays used infrequently and which may be used in an emergency are to be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

3.2.7 The relationship of a control with a display is to be immediately apparent.

3.2.8 The relationship of controls and displays with the equipment under control is to be immediately apparent.

3.2.9 There is to be adequate spacing between controls and between controls and obstructions.

3.2.10 Controls and their associated displays are to be located such that the information on the displays can be easily read during the operation of the controls.

3.2.11 Indicators related to the controls are to be visible during their operation.

3.2.12 Instruments are to face the operator's intended working position.

3.3 Physical environment

3.3.1 Control stations are to be positioned, as far as practicable, away from, or insulated against, sources of structurally transmitted noise, such as ventilation fans, engine intake fans and other noise sources.

3.3.2 In general, noise levels are to comply with IMO Res. A.468(XII), Code on Noise Levels on Board Ships, and are to take into account IMO Res. A.343(IX), *Recommendation on Methods of Measuring Noise; Levels at Listening Posts*.

3.3.3 Where provided, the heating, ventilation and air-conditioning system is to be capable of maintaining the temperature between 18°C and 27°C.

3.3.4 The flow of air from heating or air-conditioning systems is not to be guided directly to the operator, or means are to be provided to adjust the direction of airflow from those systems.

3.3.5 Lighting is to be located to avoid glare from working and display surfaces, and is to be flicker-free. Surfaces are to have a non-reflective or matt finish.

3.3.6 Placement of controls, displays and indicators are to consider the position of light sources relative to the operator with respect to reflections and evenness of lighting.

3.3.7 Where a transparent cover is fitted over a control, display or indicator, it is to be designed to minimise reflections.

3.3.8 The level of lighting is to be sufficient to enable operation of user interfaces. Lighting levels, in accordance with Table 1.3.1, will be considered to satisfy this requirement.

3.3.9 Chairs provided for use at control stations are to be adjustable to allow for varying heights of operators.

3.3.10 Physical hazards, e.g., sharp edges, protuberances and trip hazards, are to be avoided.

3.3.11 Sufficient handrails or equivalent are to be fitted to enable operators to move and stand safely in rough seas.

Table 1.3.1 Specific lighting levels

Work area	Ideal Lux	Minimum Lux
General lighting	540	220
Control room consoles (front)	540	320
Control room consoles (rear)	325	110
Local operating panels	540	320
Remote operating panels	540	320

3.3.12 Work surfaces are to be capable of withstanding oils and solvents common to ships and are to be easy to clean.

3.4 Operator interface

3.4.1 The design of the operator interface is to permit the satisfactory monitoring, control and supervision of the machinery and equipment.

3.4.2 Information is to be presented to the operator consistently, both within and between different interfaces, *see* 3.6.2 to 3.6.4.

3.4.3 The response of the machinery and equipment to operator input is to be consistent between interfaces for the same function.

3.4.4 Visual, audible or mechanical feedback is to be provided to indicate that operator input has been acknowledged.

3.4.5 Functions requested by the operator are to be confirmed by the displays on completion.

3.4.6 Indications and documentation are to be in English or the language of the crew.

3.5 Controls

3.5.1 Operator inputs are to be checked for errors, for example, out of range data or incorrect actions, and alert the operator when they occur.

3.5.2 Means to rapidly and safely correct wrong inputs or commands is to be provided.

3.5.3 Assistance is to be provided to the operator to recover from operating errors, for example, through advisory screens where the automation system has this facility.

3.5.4 Operator confirmation is to be provided for any control action that could affect the safety of the ship, i.e., they should not rely on single keystrokes.

3.5.5 The purpose of each control is to be clearly indicated. Where standard symbols have been internationally adopted, they should be used.

3.5.6 The settings of mechanical controls are to be immediately evident.

3.5.7 The means of operation of mechanical controls is to be consistent with expectations.

3.5.8 Controls or combined controls and indicators are to be distinguishable from indicators.

3.5.9 Where control is provided by touch screens, the size of the soft keys are to be of a sufficient size for operation in areas where vibration occurs or gloves are likely to be worn.

3.5.10 Where virtual keypads/keyboards or dialogue boxes are used on touch screens, they are not to obscure status or alarm areas of the display.

3.5.11 Keyboards are to be divided logically into functional areas. Alphanumeric, paging and specific keys are to be grouped separately.

3.6 Displays

3.6.1 The displays and indicators are to present the operator with clear, timely and relevant information.

3.6.2 Graphical symbols and colour coding are to be consistent. The graphical symbols of display functions are to be in accordance with a recognised International Standard, for example, ISO 14617, *Graphical symbols for diagrams.* Colour coding of functions and signals is to be in accordance with a recognised International Standard, for example, ISO 2412: 1982, *Shipbuilding – Colours of indicator lights.*

3.6.3 The symbols used in mimic diagrams for the services listed in Pt 16, Ch 2,1.5.1 are to be consistent across all displays.

3.6.4 The display of information is to be consistent with respect to screen layout and arrangement of information.

3.6.5 Flashing of information is to be reserved for unacknowledged alerts, or transient states, for example, valve moving.

3.6.6 The functions supported by a display are to be clearly indicated. For displays that can support multiple functions, it is to be possible to select the display associated with the primary function or an overview by a simple operator action.

3.6.7 The operating mode of the machinery and equipment is to be clearly indicated.

3.6.8 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

3.6.9 To indicate an increasing value in a single direction, on a fixed circular scale, the pointer is to move clockwise. If the pointer is fixed, the scale is to move anticlockwise to indicate an increase in value.

3.6.10 To indicate an increasing value on a horizontal linear scale, the pointer is to move from left to right. On a vertical linear scale, the pointer is to move upwards to indicate an increase in value.

3.6.11 The pointer is not to obscure the numbers on the scale.

3.6.12 Alphanumeric data, text, symbols and other graphical information is to be readable from relevant operator positions under lighting conditions as specified in 3.3.8. Character height in millimetres is to be not less than three and a half times the reading distance in metres and the character width is to be 0,7 times the character height.

3.6.13 A simple sans-serif character font is to be used in displays. In descriptive text, lower case letters are to be used, where appropriate, as opposed to capitals to improve readability.

3.6.14 Where information related to the safe operation of machinery and equipment is provided, it is to be continuously available to the operator.

3.6.15 Failures are to be indicated in a clear and unambiguous manner. Sufficient information is to be provided for the operator to identify the cause of the failure.

■ *Section 4* Unattended machinery space(s) – UMS notation

4.1 General

4.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in 4.2 to 4.7 are to be provided:

- Air compressors.
- Controllable pitch propellers.
- Electric generating plant.
- Oil fuel transfer and storage systems.
- Propulsion machinery including essential auxiliaries.
- Steam raising plant (boilers and their ancillary equipment).
- Thermal fluid heaters.

4.2 Alarm system for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of 2.3.

4.2.2 Audible and visual indication of machinery alarms is to be relayed to the engineers' accommodation so that engineering personnel are made aware that a fault has occurred.

4.2.3 The engineers' alarm required by 2.2.4 is to be activated automatically in the event that a machinery alarm or warning has not been acknowledged in the space within a predetermined time.

4.2.4 Audible and visual indication of machinery alarms is to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:
(a) a machinery fault has occurred,
(b) the machinery fault is being attended to, and
(c) the machinery fault has been rectified.

4.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarm parameters.

4.3 Bridge control for propulsion machinery

4.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of 2.6.

4.4 Control stations for machinery

4.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of 2.2.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of 2.8.

4.6 Bilge level detection

4.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with 2.3. This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

4.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a bilge injection or a direct bilge system, should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

4.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

4.7 Supply of electric power, general

4.7.1 For craft operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For craft operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of essential services. For the detailed requirements of these arrangements, *see* Ch 2,2.2.

■ *Section 5*
Machinery operated from a centralised control station – CCS notation

5.1 General requirements

5.1.1 Where it is proposed to operate the machinery as listed in 4.1.1 with continuous supervision from a centralised control station, the control station is to be such that the machinery operation will be as effective as it would be under direct supervision.

5.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g., stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

5.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by 4.6 together with a fire detection system satisfying the requirements of 2.8 are to be provided.

5.1.4 Additional requirements for controls, alarms and safeguards are given in 5.2.

5.2 Centralised control station for machinery

5.2.1 A centralised control station is to be provided at some suitable location, which satisfies the requirements of 5.2.2 to 5.2.7.

5.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of 2.3 and 2.5, as applicable.

5.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g., temperatures, pressures, tank levels, speeds, powers, etc.

5.2.4 Indication of the operational status of running and standby machinery is to be provided.

5.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

5.2.6 In addition to the communication required by 5.2.5, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply.

5.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

■ *Section 6* Requirements for craft which are not required to comply with the HSC Code

6.1 General

6.1.1 The relevant requirements of Sections 1 and 2 are to be complied with.

6.1.2 For vessels which are to be assigned or to be eligible for the **UMS** or **CCS** notations the requirements of Sections 4 and 5 are to be complied with.

6.1.3 For yachts less than 500 gt and small craft not requiring the **UMS** and **CCS** notation, the requirements of 6.2 and 6.3 apply.

6.1.4 Yachts that are 500 gt or more are to comply with the requirements of Sections 1 and 2.

6.2 Plans and information

6.2.1 Plans are required to be submitted in accordance with 1.2 only for the machinery items applicable to these craft.

6.3 Control and supervision of unattended machinery

6.3.1 Where machinery items applicable to these craft are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators they are to be provided with the alarms and safety arrangements specified in the appropriate Chapters of the Rules.

■ *Section 7* Trials

7.1 General

7.1.1 Before a new installation (or any alteration or addition to an existing installation) is put into service, trials are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturers' works and are to be based on the approved test schedules list as required by 1.2.3. In the case of new construction it will be expected that most of these trials will be carried out before the official sea trials of the craft. During sea trials, system dynamic tests are to be carried out to demonstrate overall satisfactory performance of the control engineering installation.

7.1.2 Means are to be provided to facilitate testing during normal machinery operation, e.g., by the provision of three-way test valves or equivalent.

7.1.3 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software life-cycle activities appropriate to the stage in the system's lifecycle at the time of system examination. The documentation required by 1.2.5 is to be in accordance with the current configuration and the testing and trials are to address software modifications and configuration management procedures to the Surveyor's satisfaction.

7.1.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

7.2 Unattended machinery space operation – UMS notation

7.2.1 In addition to the tests required by 7.1, the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
(b) Any intervention by personnel in the operation of the machinery.

7.3 Operation from a centralised control station – CCS notation

7.3.1 In addition to the tests required by 7.1, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

7.4 Record of trials

7.4.1 Two copies of the alarm and control equipment test schedules, as required by 1.2.3, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

■ *Section 1* General requirements

1.1 General

1.1.1 The requirements of Sections 1 to 19 and 21 are, in general, applicable to all the craft types indicated in Pt 1, Ch 2,2.1, with the exception of cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and for yachts less than 500 gt, which are covered in Section 20.

1.1.2 Whilst this Chapter applies to the electrical engineering equipment and systems on special service craft intended to be classed, attention should also be given to any relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered and the Code of Safety for High Speed Craft.

1.1.3 Electrical services required to maintain the craft in a normal seagoing, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power.

1.1.4 Electrical services essential for safety are to be maintained under various emergency conditions.

1.1.5 The safety of passengers, crew and craft from electrical hazards is to be ensured.

1.1.6 Consideration will be given to special cases or to arrangements which are equivalent to the Rules.

1.2 Plans required for design review

1.2.1 The plans and particulars in 1.2.2 to 1.2.13 are to be submitted for design review.

1.2.2 Single line diagram of main and emergency power and lighting systems which is to include:
(a) ratings of machines, transformers, batteries and semi-conductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables;
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted).

1.2.3 A description of operation of the main and emergency electrical power systems.

1.2.4 An earthing philosophy document that defines the basic approach to be taken for earthing the electrical power systems and all electrical loads.

1.2.5 Simplified diagrams of generator circuits, inter-connector circuits and feeder circuits showing:
(a) protective devices, e.g., short circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops;
(e) earth fault indication/protection.

1.2.6 Calculations of short circuit currents at main and emergency switchboards and section boards including those fed from transformers, with details of circuit breaker and fuse operating times and discrimination curves showing compliance with 6.1 and 11.6.2.

1.2.7 Where required by 8.1.1, the hazards resulting from electric arcs within electrical equipment and their consequences for personnel are to be identified, and at least the following supporting evidence is to be submitted:

(a) system design;
(b) operating philosophies, e.g., manual or automatic control, local or remote operation;
(c) general arrangement plans for switchboards, section boards and distribution boards, *see also* 1.3.5;
(d) general arrangement plans for the space in which the electrical equipment to be assessed are located, showing:
    (i) access to adjacent spaces;
    (ii) the location of the electrical equipment;
    (iii) ventilation arrangements for air-conditioning and/or the extraction of smoke, gas and vapours resulting from electric arcs; and
    (iv) positions within the space in which the electrical equipment is located where personnel will be performing tasks, e.g., switching, equipment maintenance, instrument observation or cleaning, or where personnel could be reasonably expected to enter;
(e) calculations in accordance with 8.3;
(f) system operating procedures; and
(g) details of defined additional safety measures to be taken during activities.

1.2.8 A test schedule which is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the public address system.

1.2.9 For battery installations, arrangement plans and calculations to show compliance with Section 12.

1.2.10 A schedule of batteries fitted for use for emergency and essential services, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life, with accompanying battery replacement procedure documentation to show compliance with 12.7.

1.2.11 Details of electrically-operated fire, craft, crew and passenger emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, to be employed for:

(a) emergency lighting;
(b) accommodation fire detection, alarm and extinction systems;
(c) fixed water-based local application fire-fighting systems;
(d) public address system;
(e) general emergency alarm;
(f) watertight doors, shell doors and other electrically operated closing appliances; and
(g) low location lighting.

NOTE
A general arrangement plan of the complete craft showing the main vertical fire zones and the location of equipment and cable routes, including identification of relevant high fire risk areas, for the above systems, is to be made available for the use of the Surveyor on board.

1.2.12 Evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas, as required by 17.3.11 and 17.3.12, including a schedule of electrical and electronic equipment located in protected areas and adjacent areas, and general arrangement plans showing the coverage of the protected areas and adjacent areas.

1.2.13 Schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected. The following details are to be provided to meet this requirement:

(a) a description of the expected operating profiles (e.g. the number of generating sets connected when manoeuvring, at sea, etc.), including as required by Pt 5, Ch 2,1.1.1; and
(b) a schedule of the normal and emergency operating loads, which is to state the kilowatt rating of each load and a load factor between 0 and 1 that reflects:
    (i) the duty cycle of the load; and
    (ii) the proportion of its maximum rating at which the load is expected to operate.

1.3 Plans required for supporting evidence

1.3.1 The plans and particulars in 1.3.2 to 1.3.5 are to be submitted as supporting evidence.

1.3.2 In order to establish compliance with 1.11.2 and 5.1.3 to 5.1.5, a general arrangement plan of the craft showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying essential and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.3.3 Arrangement plans of main and emergency switchboards, and section boards, and documentation that demonstrates that creepage and clearance distances are in accordance with 7.5.

1.3.4 In order to establish compliance with the requirements of 1.7.3, when requested, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.3.5 For non-metallic cable support systems or protective casings, test evidence, details of installation procedures and manufacturer's recommendations that show compliance with 11.13.

1.4 Surveys

1.4.1 Electrical machinery and auxiliary services essential for the safety of the craft are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.4.2 The following equipment, where intended for use for essential and emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and
- UPS units of 50 kVA and over.

1.4.3 For electric propulsion systems, in addition to the equipment listed in 1.4.2, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- exciters;
- filters;
- reactors;
- dynamic braking assemblies;
- pre-magnetisation transformers; and
- slip ring assemblies.

1.4.4 All other electrical equipment, not specifically referenced in 1.4.2 and 1.4.3, intended for use for essential or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of this Chapter.

1.5 Additions or alterations

1.5.1 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.5.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey, and to the satisfaction of the Surveyors.

1.5.3 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be adequate ventilation in accordance with 12.5.9 and that the location and installation requirements of 12.3 and 12.4 are complied with.

1.5.4 Proposed modifications to the electrical protection systems are to be developed in accordance with 6.1.4 and plans submitted are also to address the updating of approved version of the details required by 1.2.5 and 1.2.6.

1.5.5 Where it is intended to replace an existing incandescent lamp type navigation light with a light emitting diode type navigation light, details are to be submitted for consideration that demonstrate compliance with 15.3. Light emitting diode type navigation light failure detection arrangements are to satisfy the requirements of 15.3.5 and 15.3.6.

1.6 Definitions

1.6.1 Essential services are those necessary for the propulsion and safety of the craft, such as the following:

- air compressors for starting and manoeuvring essential mains and auxiliary machinery;
- air pumps:
- automatic sprinkler systems;
- ballast pumps;
- bilge pumps;
- circulating and cooling water pumps;
- communication systems;
- electric starting systems for starting and manoeuvring essential main and auxiliary machinery;
- fire detection and alarm systems;
- fire pumps;
- fuel valve cooling pumps;
- hydraulic pumps for controllable pitch propellers and those serving essential services here listed that would otherwise be directly electrically-driven;
- hydraulic pumps serving essential services here listed which would otherwise be directly electrically driven;
- lubricating oil pumps;
- lighting systems for those parts of the craft normally accessible to and used by personnel and passengers;
- navigational aids where required by Statutory Regulations;
- navigation lights and special purpose lights where required by Statutory regulations;
- oil fuel pumps and oil fuel burning units;
- pumps for fire-extinguishing systems;
- scavenge blowers;
- steering gear;
- valves which are required to be remotely operated;
- ventilating fans for engine rooms;
- watertight doors, shell doors and other electrical operated closing appliances;
- windlasses;
- power sources and supply systems for supplying the above services.

1.6.2 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

1.6.3 Services such as the following, which are additional to those in 1.6.1 and 1.6.2, are considered necessary to maintain the craft in a normal seagoing operational and habitable condition:

- cargo handling and cargo care equipment;
- hotel services, other than those required for habitable conditions;
- thruster systems for manoeuvring.

1.6.4 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also* 5.1.2.

1.6.5 A 'switchboard' is a switchgear and control gear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.6.6 A 'section board' is a switchgear and control gear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.6.7 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.6.8 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.6.9 'Special Category spaces' are those enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel, for their own propulsion, in their tanks, into and from which such vehicles can be driven, and to which passengers have access.

1.6.10 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

1.6.11 'Dead craft condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be available at all times to start the emergency generator, *see* Pt 10, Ch 1,7.6.

1.6.12 Protected space is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.6.13 Protected areas are areas within a protected space which is required to be protected by a fixed water-based local application fire-fighting system.

1.6.14 Adjacent areas are areas, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.6.15 An 'electric arc' is an electrical discharge or a short-circuit through ionised air caused by isolation or insulation integrity failure.

1.6.16 'Incident energy' is the amount of energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

1.7 Design and construction

1.7.1 Equipment for services essential for the safety of the craft are to be constructed in accordance with the relevant requirements of this Chapter.

1.7.2 The design and installation of other equipment is to be such that risk of fire due to its failure is minimised. It is to, as a minimum, comply with a National or International Standard revised where necessary for ambient conditions.

1.7.3 Electrical equipment is to be suitable for its intended purpose and accordingly, whenever practicable to be selected from the *List of Type Approved Products* published by Lloyd's Register's (hereinafter referred to as 'LR'). A copy of the Procedure for LR Type Approval System will be supplied on application.

1.8 Quality of power supplies

1.8.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for essential and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

1.8.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals. Alarms are to be provided for High and Low Voltage and Low Frequency.

(a) Voltage:
  - permanent variations +6 per cent, –10 per cent
  - transient variations due to step changes in load ±20 per cent
  - recovery time 1,5 seconds.

(b) Frequency:
  - permanent variations ±5 per cent
  - transient variations due to step changes in load ±10 per cent
  - recovery time 5 seconds.

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

1.8.3 Harmonics. Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any a.c. switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental,

expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h^2}}{V_1} \times 100$$

where

V_h = rms amplitude of a harmonic voltage of order h

V_1 = rms amplitude of the fundamental voltage.

1.8.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:

Voltage tolerance (continuous) ±10 per cent
Voltage cyclic variation deviation 5 per cent
Voltage ripple 10 per cent

(a.c. rms over steady state d.c. voltage);

(b) When supplied by batteries:

(i) Equipment connected to the batteries during charging:
Voltage tolerance +30 per cent, –25 per cent;

(ii) Equipment not connected to batteries during charging:
Voltage tolerance +20 per cent, –25 per cent

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

1.9 Ambient reference and operating conditions

1.9.1 The rating for classification purposes of essential electrical equipment intended for installation in craft to be classed for unrestricted (geographical) service is to be based on an engine room ambient temperature of 45°C, and a seawater temperature at the inlet of 32°C. The equipment manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

1.9.2 In the case of craft to be classed for restricted service, the rating is to be suitable for the ambient conditions associated with the geographical limits of the restricted service which are part of the class notation.

1.9.3 Main and essential auxiliary machinery and equipment is to operate satisfactorily under the conditions shown in Pt 9, Ch 1,4.4. Electrical equipment satisfying alternative ambient operating condition requirements for installation on ships contained in an acceptable and relevant national or international standard may be considered to satisfy this requirement.

NOTE

Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements.*

1.9.4 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that, in the event of loss of one cooling unit, for any reason, the remaining unit(s) will be capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safely within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for an ambient temperature of not less than 45°C; and
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

See also Ch 1,1.3.3.

1.9.5 Where equipment is to comply with 1.9.4, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

1.9.6 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with 1.9.4 are considered essential services and are to satisfy the requirements of 5.2.

1.10 Inclination of craft

1.10.1 Emergency and essential electrical equipment is to operate satisfactorily under the conditions as shown in Table 1.4.1 in Pt 9, Ch 1.

1.11 Location and construction

1.11.1 All electrical equipment is to be constructed or selected, and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplied at the safety voltage specified in 1.12.2(h);

(b) it does not cause injury when handled or touched in the normal manner; and

(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201 for the relevant location will satisfy these requirements.

1.11.2 Switchboards, section boards and distribution boards supplying essential and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

1.11.3 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;

(b) clear of flammable material;

(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in 1.9;
(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe-type', *see* Section 14;
(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

1.11.4 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:
(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;
(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and
(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

NOTE
Compliance with IEC 60695: *Fire hazard testing*, or an alternative and acceptable Standard, will satisfy this requirement, *see also* 1.16.4.

1.11.5 Insulating materials and insulated windings are to be resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

1.11.6 The minimum creepage and clearance distances provided for electrical connections, terminals and similar bare live parts are to be in accordance with a relevant International or National Standard for the equipment or apparatus concerned. In cases where the rated voltage is outside that given in the Standard or where no Standard is available, the minimum creepage and clearance distances provided are to be in accordance with 7.5. Details of alternatives proposals including supporting design rationale and demonstration may be submitted for consideration.

1.11.7 Studs, screw-type or spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also* 11.15. There is to be adequate space and access for the terminations.

1.11.8 The design of equipment is to enable ease of access to all parts requiring inspection or replacement in service.

1.11.9 Equipment is not to remain alive through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs.

1.11.10 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice.

1.11.11 All nuts, screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

1.11.12 To allow ease of access, connectors are to be spaced far enough apart to permit connection and disconnection. At test points, adequate clearance is to be provided between connection points and controls to provide access for testing.

1.11.13 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

1.11.14 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level, under the normal angles of inclination given in 1.10 for essential electrical equipment, *see* Pt 15, Ch 2.

1.12 Earthing of non-current carrying parts

1.12.1 Except where exempted by 1.12.2, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

1.12.2 The following parts may be exempted from the requirements of 1.12.1:
(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 50 V d.c. or 50 V a.c., between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

1.12.3 Where extraneous-conductive parts (i.e. parts not forming part of the electrical installation and liable to introduce an electric potential) are not bonded by separate earthing conductors, details are to be submitted that demonstrate that a permanent, metal-to-metal connection of negligible impedance, which will not degrade due to corrosion or vibration, will be achieved.

1.12.4 Armouring, braiding and other metal coverings of cables are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See* 14.1 for earthing of cables in hazardous zones or spaces.

1.12.5 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

1.12.6 Metal parts of portable appliances, other than current-carrying parts and parts exempted by 1.12.2 are to be earthed by means of an earth-continuity conductor in the flexible cable or cord through the associated plug and socket-outlet.

1.12.7 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration.

1.12.8 The nominal cross-section areas of copper earthing conductors are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2. Every other earthing conductor is to have a conductance not less than that specified for an equivalent copper earthing conductor.

1.12.9 The connection of the earthing conductor to the hull of the craft is to be made in an accessible position, and is to be secured by a screw or stud of a diameter appropriate for the size of earthing conductor, but not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

1.13 Electrical bonding for the control of static electricity

1.13.1 In non-metallic craft, all metallic parts of the craft are to be electrically bonded together, as far as possible, in consideration of galvanic corrosion between dissimilar metals, to ensure an earth return path and to connect the craft to the water when water-borne. This does not apply to isolated components which cannot become live, nor require control of static electricity.

1.13.2 Bonding straps for the control of static electricity are required for piping systems, including pressure refuelling points, which are not electrically continuous throughout their length and for flammable products, which are not permanently connected to the hull of the craft either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

1.13.3 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of at least 10 mm^2, and are to comply with 1.12.7 and 1.12.9.

1.14 Labels, signs and notices

1.14.1 Labels, signs and notices required by this Chapter are to be positioned in clearly visible locations which will not be obscured.

1.14.2 Labels, signs and notices are to be easy to read under the expected operating conditions. Character height in accordance with Table 2.1.1 will be considered to satisfy this requirement.

Table 2.1.1 Character height and viewing distance

Work area	Minimum character height (mm)
Less than 500	2,3
500–1000	4,7
1000–2000	9,4
2000–4000	19
4000–8000	38

1.14.3 Controls, indicators and displays required by this Chapter are to be labelled to indicate their function. Labels are to be positioned in a manner that associates the label with the item being labelled.

1.14.4 Labels, signs and notices are to use short, clear messages. In general, warning signs and notices are to comprise:

- a word signalling the gravity of the risk (e.g., Danger, Warning or Caution);
- a statement of the nature and/or consequence of the hazard; and
- wherever practical, an instruction giving appropriate behaviour to avoid the hazard.

1.15 Alarms

1.15.1 Where alarms are required by this Chapter they are to be arranged in accordance with Ch 1,2.3. Sound signal equipment, fire and general alarm bells are not required to be supplemented by visual indications, except in areas having high levels of background noise, such as machinery spaces.

1.15.2 The alarms in this Chapter are additional to those required by Chapter 1. They may however form part of the alarm system that is required by Chapter 1.

1.15.3 Cables for emergency alarms and their power sources are to be in accordance with 1.16.

1.15.4 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see* 1.16.

1.16 Operation under fire conditions

1.16.1 As a minimum, the following emergency services and their emergency power supplies, are required to be capable of being operated under fire conditions:

- Emergency fire pump.
- Fire safety stops, *see also* 17.6.
- Control and power systems to power-operated watertight doors and status indication for all fire doors.
- Control and power systems to power-operated fire doors and their status indication.
- Emergency lighting.
- Fire and general alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Low location lighting, *see also* 18.4.3.
- Public address systems.

1.16.2 Where cables for services that are required to be capable of being operated under fire conditions, including their power supplies, pass through high fire risk areas, main vertical or horizontal fire zones or decks other than those which they serve, they are to be of a fire resistant type complying with 11.5.3, and:

(a) in the case of the emergency services: the fire resistant cable is to extend, at least, from the control/monitoring panel to the nearest local junction box serving the relevant deck/area; and

(b) in the case of power supplies: the fire resistant cable is to extend, at least, from the distribution point within the space containing the emergency source of electrical power to the nearest local distribution panel serving the relevant deck/area.

1.16.3 Electrical cables for the above services required to be capable of being operated under fire conditions, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

1.16.4 In addition to 1.11.4, materials used for electrical equipment, cables and accessories within passenger accommodation areas are not to be capable of producing excessive quantities of smoke and toxic products, when tested in accordance with an acceptable and relevant Standard.

1.17 Lightning protection

1.17.1 In order to minimise the risks of damage to the craft and its electrical installation due to lightning, crafts having non-metallic masts or topmasts are to be fitted with lightning conductors in accordance with the applicable requirements of IEC 60092-401 *Electrical installations in ships. Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

1.17.2 In addition to the primary protection requirements in 1.17.1, precautions are to be taken to protect essential electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

1.18 Programmable electronic systems

1.18.1 Where programmable electronic systems are implemented and used to control the electrical installation, or to provide safety functions in accordance with the requirements of this Chapter (e.g. electric propulsion, circuit-breaker settings, switchgear and control gear controllers, etc.), the arrangements are to satisfy the applicable requirements of Ch 1,2.10 to 2.13.

1.18.2 Where 1.18.1 applies, proposed modifications to software and acceptance testing and trials are to be in accordance with Ch 1,1.4 and Section 7 as applicable.

■ *Section 2* Main source of electrical power

2.1 General

2.1.1 The main source of electrical power is to comply with the requirements of this Section without recourse to the emergency source of electrical power.

2.2 Number and rating of generators and converting equipment

2.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for essential equipment and habitable conditions;

(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to stall or any device to fail due to excessive voltage drop on the system;

(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a ‘dead craft condition’. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by Section 3, *see also* 2.3.2.

2.2.2 The arrangement of the craft’s main source of power is to be such that the operation of electrical services for essential equipment and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

2.2.3 Where the electrical power requirement to maintain the craft in a normal operational and habitable condition is usually supplied by one generating set, arrangements are to be provided to prevent overloading of the running generator, *see* 6.9. On loss of power there is to be provision for automatic starting and connecting to the main switchboard of the standby set in as short a time as practicable, but in any case within 45 seconds, and automatic sequential restarting of essential services, *see* 1.6.1, in as short a time as practicable.

NOTE

Where the prime mover starting time will result in exceeding this starting and connection time, details are to be submitted for consideration.

2.3 Starting arrangements

2.3.1 The starting arrangements of the generating sets' prime movers are to comply with the requirements of Pt 10, Ch 1 and 2 as applicable.

2.3.2 Where the emergency source of electrical power is required to be used to restore propulsion from a 'dead craft condition', the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the 'dead craft condition'. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in 3.2.7(a), 3.2.7(b), 3.2.7(c) for passenger craft and yachts greater than 500gt; or 3.3.7(a), 3.3.7(b), 3.3.7(c) and 3.3.7(d)(i) and (vi) for craft required to comply with HSC code; or 3.4.3(a) to (e) and (f) (i) as applicable. *See* Pt 10, Ch 1,7.1.1 and Ch 2,6.1.1 for starting arrangements.

2.4 Prime mover governors

2.4.1 The governing accuracy of the generating sets' prime movers is to meet the requirements of Pt 10, Ch 1 and Ch 2.

2.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in 1.8.2, *see also* Pt 10, Ch 1 and Ch 2.

2.5 Main propulsion driven generators not forming part of the main source of electrical power

2.5.1 Generators and generator systems, having the craft's propulsion machinery as their prime mover but not forming part of the craft's main source of electrical power may be used whilst the craft is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of 2.5.2 to 2.5.4 are satisfied.

2.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

2.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that essential machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

2.5.4 In addition to the requirements of 2.2.3, arrangements are to be fitted to automatically start one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ *Section 3* Emergency source of electrical power

3.1 General

3.1.1 The requirements of this Section apply to passenger craft, to yachts that are 500 gt or more, to cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above, and to cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 and 5. For other craft, *see* Section 20.

3.1.2 Passenger craft and cargo craft constructed in compliance with the HSC Code are to comply with 3.3. Other specified craft are to comply with 3.2 or 3.4 as applicable.

3.1.3 The emergency source of power for other craft will be the subject of special consideration, with due regard to the size and the intended service of the craft.

3.1.4 Where the main source of electrical power is located in two or more compartments which are not contiguous, each of which has its own self-contained systems, including power distribution and control systems, completely independent of each other and such that a fire or other casualty in any one of the spaces will not affect the power distribution from the others, or to the services required by 3.2, 3.3 or 3.4, the requirements of this Section may be considered satisfied without an additional emergency source of electrical power, provided that:

(a) there is at least one generating set of sufficient capacity to meet the requirements of 3.2, 3.3 or 3.4 in each of at least two non-contiguous spaces;

(b) the generator sets referred to in 3.1.4(a) and their self-contained systems are installed such that a source of electrical power remains available at all times to supply emergency services after damage or flooding in any one compartment.

3.1.5 Non-passenger type craft of 300 tons gross tonnage and above are to comply with 3.7.

3.2 Emergency source of electrical power in passenger craft and for yachts that are 500 gt or more

3.2.1 A self-contained emergency source of electrical power is to be provided.

3.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted. Consideration may also be given to alternative arrangements, such as 3.1.4, which provide an equivalent degree of safety from fire and flooding.

3.2.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

3.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.2.5 Where compliance with 3.2.3 or 3.2.4 is not practicable, details of the proposed arrangements are to be submitted.

3.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used exceptionally, and for short periods, to supply non-emergency circuits. Failure of the emergency switchboard when being used in other than an emergency is not to put at risk the operation of the craft or yacht.

3.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 36 hours, emergency lighting:
  (i) at every lifeboat or liferaft preparation station, muster and embarkation station and oversides;
  (ii) in alleyways, stairways and exits, giving access to the muster and embarkation stations;
  (iii) in all service and accommodation alleyways, stairways and exits and personnel lift cars;
  (iv) in the machinery spaces, and main generating stations including their control positions;
  (v) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (vi) at the stowage positions for firemen's outfits and life saving appliances;
  (vii) at the steering gear; and
  (viii) at the fire pump, the sprinkler pump and the emergency bilge pump and at the starting position of their motors.

(b) for a period of 36 hours:
  (i) the navigation lights, and other lights as required by the International Regulations for Preventing Collisions at Sea in force; and
  (ii) the radiocommunications, as required by statutory regulations.

(c) for a period of 36 hours:
  (i) all internal communication equipment required in an emergency;
  (ii) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable this requirement may be waived for craft of less than 5000 tons gross;
  (iii) the fire detection, fire alarm and general alarm system, manual alarms, and the fire door holding and release system; and
  (iv) the intermittent operation of the daylight signalling lamps, the craft's whistle, the manually-operated call points and all internal signals that are required in an emergency;

  unless such services have an independent supply for the period of 36 hours from an accumulator battery, suitably located for use in an emergency;

(d) for a period of 36 hours:
  (i) emergency fire pump;
  (ii) the automatic sprinkler pump, if fitted;
  (iii) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
  (iv) essential electrically powered instruments and control for propulsion machinery, if alternate sources of power are not available for such devices.

(e) for a period of 10 min, power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;

(f) for a period of half an hour;
   (i) any watertight doors required by Chapter 2 to be power operated together with their control, indication and alarm signals;
   (ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency;
(g) where applicable, the services required by 2.3.2; and
(h) where applicable, the air compressors for breathing apparatus cylinders referred to in 17.10.1.

3.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:
(a) Where the emergency source of electrical power is a generator it is to be:
   (i) driven by a suitable prime mover with an independent supply of fuel having a flash point (closed cup test) of not less than 43°C;
   (ii) started automatically upon failure of the electrical supply from the main source of electrical power and is to be automatically connected to the emergency switchboard; those services referred to in 3.2.7 are then to be transferred automatically to the emergency generating set. The automatic starting system and the characteristics of the prime mover are to be such as to permit the emergency generator to carry its full rated load as quickly as is safe and practicable, subject to a maximum of 45 seconds; and
   (iii) provided with a transitional source of emergency electrical power according to 3.2.9.
(b) Where the emergency source of electrical power is an accumulator battery, it is to be capable of:
   (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
   (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
   (iii) immediately supplying at least those services specified in 3.2.9.

3.2.9 The transitional source of emergency electrical power required by 3.2.8 may consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and so arranged as to supply automatically in the event of failure of either the main or emergency source of electrical power for half an hour at least the following services, if they depend upon an electrical source for their operation:
(a) (i) the lighting required by 3.2.7(a) and (b);
   (ii) the services required by 3.2.7(c)(i), (iii) and (iv) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency;
(b) with respect to watertight doors:
   (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
   (ii) power to the control, indication and alarm circuits for the watertight doors.

3.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

3.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

3.2.12 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of emergency electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

3.2.14 In order to ensure the ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

3.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

3.2.16 In addition to the emergency lighting required by 3.2.7(a) passenger craft with roll on–roll off cargo spaces or special category spaces, are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service.
(b) A portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.2.17 A lesser period than the 36 hour period specified in 3.2.7, but not less than 18 hours, may be considered for yachts of 500 gt or more when in accordance with the relevant Statutory Regulations of the National Authority of the country in which the craft is to be registered.

3.3 Emergency source of electrical power in craft required to comply with the HSC Code

3.3.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.6, 3.2.8, 3.2.11 and 3.2.13 to 3.2.15.

3.3.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the waterline in the final condition of damage, be operable in that condition, and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead, if fitted.

3.3.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and
- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any, and;
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard;
- or in any machinery space;

will not interfere with the supply, control and distribution of emergency electrical power.

3.3.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces and those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

3.3.5 Where compliance with 3.3.3 or 3.3.4 is not practicable, details of the proposed arrangements are to be submitted.

3.3.6 For passenger craft with the restrictive notation Passenger (A), the emergency source of power is to be capable of supplying simultaneously the services referred to in 3.3.7(a), 3.3.7(b) and 3.3.7(d)(ii) and (vi), for a period of 5 hours, the services referred to in 3.3.7(c) and (e) for the periods specified, and, additionally, the 'Not under command' lights for a period of 12 hours.

3.3.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of 12 hours, emergency lighting:
   (i) at the stowage positions of life-saving appliances and, additionally, for passenger craft at the preparation, launching and deployed positions of survival craft and equipment for embarkation into those craft;
   (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
   (iii) in the passenger compartments or public spaces, if any;
   (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
   (v) in control stations;
   (vi) at the stowage positions for fireman's outfits; and
   (vii) at the steering gear;
(b) for a period of 12 hours:
   (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force;
   (ii) electrical internal communication equipment for announcements during evacuation;
   (iii) fire detection and general alarm system and manual fire-alarms; and
   (iv) remote control devices of fire-extinguishing systems if electrical;
(c) for a period of four hours of intermittent operation:
   (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
   (ii) the craft's whistle or siren, if electrically driven;

(d) for a period of 12 hours:
   (i) the navigational equipment as required by statutory Regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 gross tonnage;
   (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
   (iii) emergency fire pump;
   (iv) the automatic sprinkler pump and drencher pump, if fitted;
   (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves; and
   (vi) the craft radio facilities required to be available in an emergency;
(e) for a period of 10 minutes:
   (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4;
(f) for Passenger (B) craft only, for a period of half an hour:
   (i) power operated sliding watertight doors together with their indicators and warning signals.
(g) for any passenger high speed craft with lifts, for a period of half an hour:
   (i) the emergency arrangements to bring the lift cars to deck level for the escape of persons. The passenger lift cars may be brought to deck level sequentially in an emergency.

3.3.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:
(a) Where the emergency source of electrical power is a generator it is to be:
   (i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed cup test) of not less than 43° C;
   (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power complying with 3.3.9 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.3.9 are to be connected automatically to the emergency generator; and
   (iii) provided with a transitional source of emergency electrical power as specified in 3.3.9, except on cargo craft where it may be omitted when an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.
(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
   (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
   (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
   (iii) immediately supplying at least those services specified in 3.3.9.

3.3.9 The transitional source of emergency electrical power where required by 3.3.8 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:
(a) the lighting required by 3.3.7(a) and (b). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces, may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and
(b) the services required by 3.3.7(b) and (c);
(c) with respect to watertight doors:
   (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times, i.e. closed-open-closed, against an adverse list of 15°; and
   (ii) power to the control, indication and alarm circuits for the watertight doors.

Alternatively, the above services may have independent supplies, for the period specified, from accumulator batteries suitably located for use in an emergency.

3.3.10 For passenger craft, propulsion and direction system instruments and controls power supplies are to be arranged to provide an uninterruptible supply of emergency power.

3.3.11 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator is to be mounted in a suitable place in the craft's operating compartment to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged, and provision is to be made to charge them *in situ* from a reliable on board supply.

3.3.12 In addition to the emergency lighting required by 3.3.5(a) to (c), passenger craft with roll on-roll off spaces are to be provided with the following:

(a) in all passenger public spaces and alleyways supplementary electric lighting that can operate for at least three hours when all other sources of electric power have failed and under any condition of heel. The illumination provided is to be such that the approach to the means of escape can be readily seen. The source of power for the supplementary lighting is to consist of accumulator batteries within the lighting units that are continuously charged, where practicable, from the emergency switchboard. Consideration may be given to other means of lighting which is at least as effective. The supplementary lighting is to be such that any failure of the lamp will be immediately apparent. Any accumulator battery provided is to be replaced at intervals having regard to the specified service life in the ambient conditions that they are subject to in service; and

(b) a portable rechargeable battery operated lamp is to be provided in every crew space alleyway, recreational space and every working space which is normally occupied unless supplementary emergency lighting, as required by (a) is provided.

3.4 Emergency source of electrical power in cargo craft, patrol and pilot craft, workboats and other similar craft of 500 tons gross tonnage and above; and cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 4 to 6

3.4.1 The arrangements for the emergency source of electrical power are to satisfy the requirements of this sub-Section and, additionally, 3.2.1, 3.2.3, 3.2.6 and 3.2.10 to 3.2.15.

3.4.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located such that the emergency generator and the main generators together meet the requirements of 3.1.4(a) and (b).

3.4.3 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter, if they depend upon an electrical source for their operation:

(a) for a period of three hours, emergency lighting at every survival craft preparation station, muster and embarkation station and over the sides;

(b) for a period of 12 hours, emergency lighting:
  - (i) at the stowage positions of life-saving appliances:
  - (ii) at all escape routes, such as alleyways, stairways, exits from accommodation and service spaces, embarkation points, etc.;
  - (iii) in the public spaces, if any;
  - (iv) in the machinery spaces, and main emergency generating spaces including their control positions;
  - (v) in control stations;
  - (vi) at the stowage positions for fireman's outfits;
  - (vii) at the steering gear; and
  - (viii) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors;

(c) for a period of 12 hours:
  - (i) the navigation lights, and other lights required by the *International Regulations for Preventing Collisions at Sea* in force; and
  - (ii) the radio communications, as required by statutory regulations;

(d) for a period of 12 hours:
  - (i) electrical internal communication equipment for announcements during evacuation;
  - (ii) fire detection and general alarm system and manual fire alarms; and
  - (iii) remote control devices of fire-extinguishing systems if electrical;

  unless such services have an independent supply for a period of 12 hours from an accumulator battery, suitably located for use in an emergency;

(e) for a period of four hours of intermittent operation:
  - (i) the daylight signalling lamps, if they have no independent supply from their own accumulator battery; and
  - (ii) the craft's whistle or siren, if electrically driven;

(f) for a period of 12 hours:
  - (i) the navigational equipment as required by statutory regulations; where such provision is unreasonable or impracticable, this requirement may be waived for craft of less than 5000 tons gross tonnage;
  - (ii) essential electrically powered instruments and controls for propulsion machinery, if alternate sources of power are not available for such devices;
  - (iii) emergency fire pump;
  - (iv) the automatic sprinkler pump and drencher pump, if fitted; and
  - (v) the emergency bilge pump and all the equipment essential for the operation of electrically powered remote controlled bilge valves;

(g) for a period of 10 min:
  - (i) power drives for directional control devices including those required to direct thrust forward and astern, unless there is a manual alternative complying with Pt 14, Ch 1,6.1.4.

(h) for a period of half an hour:
  - (i) any watertight doors required by Chapter 2 to be power-operated together with their indicators and warning signals; and

(j) where applicable, the services required by 2.4.2.

3.4.4 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:
  (i) driven by a suitable prime mover with an independent supply of fuel, having a flash point (closed cup test) of not less than 43°C;
  (ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with 3.4.5 is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in 3.4.5 are to be connected automatically to the emergency generator; and
  (iii) provided with a transitional source of emergency electrical power as specified in 3.4.5 unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:
  (i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
  (ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power; and
  (iii) immediately supplying at least those services specified in 3.4.5.

3.4.5 The transitional source of emergency electrical power where required by 3.4.4 is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power for half an hour at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by 3.4.3(a) to (c). For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps, and

(b) all services required by 3.4.3(d)(i) to (iii) and (e) unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(c) with respect to watertight doors:
  (i) power to operate the watertight doors but not necessarily simultaneously, unless an independent temporary source of stored energy is provided. The power source should have sufficient capacity to operate each door at least three times i.e. closed-open-closed, against an adverse list of 15°;
  (ii) power to the control, indication and alarm circuits for the watertight doors for half an hour.

3.5 Starting arrangements

3.5.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in Part 10.

3.6 Prime mover governor

3.6.1 Where the emergency source of power is a generator, the governor is to comply with 2.4.

3.7 Radio installation

3.7.1 Every radio installation as required by statutory regulations is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

3.7.2 A reserve source or sources of energy is to be provided on every craft, for the purpose of conducting distress and safety radio-communications, in the event of failure of the craft's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the craft is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT 'ship to earth' station and any of the additional loads mentioned in 3.7.4, 3.7.5 and 3.7.7 for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

3.7.3 The reserve source or sources of energy is to be independent of the propelling power of the craft and the craft's electrical system.

3.7.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in 3.7.2, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by 3.7.2, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or

(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

3.7.5 The reserve source or sources of energy may be used to supply the electrical lighting required by 3.7.1.

3.7.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

3.7.7 If an uninterrupted input of information from the craft's navigational or other equipment to a radio installation as referred to in 3.7.2 is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the craft's main or emergency source of electrical power.

■ *Section 4* External source of electrical power

4.1 Temporary external supply (shore supply)

4.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing a circuit-breaker or isolating switch and fuses and terminals including one earthed, of ample size and suitable shape to facilitate a satisfactory connection of three-phase external supplies with earthed neutrals.

4.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

4.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

4.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

4.1.5 Alternative arrangements may be submitted for consideration.

4.2 Permanent external supply

4.2.1 Details are to be submitted.

■ *Section 5* Supply and distribution

5.1 Systems of supply and distribution

5.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase;
three-wire;
four-wire with neutral solidly earthed but without hull return.

5.1.2 System voltages for both alternating current and direct current in general are not to exceed:

(a) 15 000 V for propulsion purposes;
(b) 500 V for power, cooking and heating equipment permanently connected to fixed wiring;
(c) 250 V for lighting, heaters in cabins and public rooms, and other applications not mentioned above;
(d) Voltages exceeding these will be the subject of special consideration.

5.1.3 The arrangement of the main system of supply is to be such that a fire or other casualty in any space containing the main source of electrical power, associated converting equipment, if any, the main switchboard or the main lighting switchboard will not render inoperable any emergency service, other than those located within the space where the fire or casualty has occurred.

5.1.4 The main switchboard is to be so placed relative to the main source of power that, as far as is practicable, the integrity of the main system of supply will be affected only by a fire or other casualty in one space.

5.1.5 The arrangement of the emergency system of supply is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the craft.

5.1.6 Distribution systems required in an emergency are to be so arranged that a fire in any main vertical zone will not interfere with the emergency distribution in any other such zone.

5.1.7 Feeders from the main and the emergency sources of electrical power are to be separated both vertically and horizontally as widely as is practicable.

5.1.8 For Passenger (A) or Passenger (B) Craft or cargo craft of 500 tons gross tonnage and over, and in any case where the total installed electrical power of the main generating sets is in excess of 3 MW or is supplied at high voltage, arrangements are to be made so that it is possible to split the switchboard, by a multipole linked circuit-breaker, disconnector or switch-disconnector, into at least two independent sections, each supplied by at least one generator.

5.1.9 Where 5.1.8 is applicable and the essential services which are duplicated are supplied from a section board, arrangements are to be made so that it is possible to split the section board into at least two independent sections each supplied by an independent section of the main switchboard either directly or through a transformer.

5.1.10 For Passenger (B) high speed craft, each part of the main busbars with its associated generators is to be arranged in separate compartments.

5.2 Essential services

5.2.1 Essential services that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or control gear assemblies, so that any single fault will not cause the loss of both services.

5.2.2 Where 5.2.1 is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by removable links or other means, into at least two independent sections, each supplied by at least one generator, either directly or through a converter. The essential services are to be equally divided, as far as is practicable, between the independent sections.

5.2.3 Where 5.1.8 is applicable provision is to be made to transfer to a temporary circuit those essential services which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section board.

5.2.4 Where the loss of the electrical supply to a particular essential service which is not duplicated would cause serious risk to the craft, it is to be fed by two independent supplies complying with 5.2.1. Such circuits are to be provided with short circuit protection and an overload and phase-failure alarm. Failure of either supply is not to cause risk to the craft during switching to the alternative supply.

5.3 Isolation and switching

5.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:
(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.
Precautions are to be taken to minimise the risk of inadvertent or accidental switching.

5.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:
(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit.
In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches. For circuit-breakers, *see* 6.5 and 7.3.

5.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:
(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

5.3.4 All lighting and power circuits installed in unattended spaces are to be controlled by multipole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

5.3.5 Where arrangements are in place for automatic changeover between two or more supplies of electrical power in the event of failure of one supply, the arrangements are to be such that a fault in one feeder does not result in the loss of all supplies to the automatic changeover switch.

5.3.6 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit.

5.3.7 The switching device required by 5.3.6 is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

5.3.8 A notice is to be fixed to any section board, distribution board or item of equipment to which 5.3.5 applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

5.4 Insulated distribution systems

5.4.1 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance.

5.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

5.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

5.5 Earthed distribution systems

5.5.1 No fuse, non-linked switch or non-linked circuit-breaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

5.5.2 For high speed craft, earthed electrical distribution systems are not to be used, with the exception of earthed intrinsically safe circuits, in areas where an explosive gas atmosphere may arise from the presence of fuel with a flash point below 43°C, *see* Pt 15, Ch 3,3.1.

5.5.3 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short circuit current for which the generators are designed.

5.5.4 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

5.5.5 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

5.5.6 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

5.5.7 All earthing impedances are to be connected to a common earth connection/bar. The connections to the common earth connection/bar are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

5.6 Diversity factor

5.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connection load before application of any diversity factor.

5.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

5.6.3 For winches and crane motors the diversity factor is to be calculated and submitted when required.

5.7 Lighting circuits

5.7.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A. (This does not apply to cabin and wardrobe heaters).

5.7.2 Lighting for machinery spaces, control stations, normal working spaces, large galleys, corridors, stairways leading to boat decks and in public rooms is to be supplied from at least two final sub-circuits in such a way that failure of any one of the circuits does not leave the space in darkness. One of these circuits may be the emergency circuit, provided it is normally energised.

5.7.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other.

5.7.4 Emergency lighting is to be fitted in accordance with Section 3, *see also* Section 18.

5.8 Motor circuits

5.8.1 A separate final sub-circuit is to be provided for every motor for essential services, *see* 1.6.1.

5.9 Motor control

5.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in 5.9.2 to 5.9.4.

5.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

5.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also* 6.9.

5.9.4 Motor control gear is to be suitable for the starting current and for the full load rated current of the motor.

Section 6
System design – Protection

6.1 General

6.1.1 Installations are to be protected against over-currents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:
(a) availability of essential and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

6.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

6.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency or essential services other than those dependent on the circuit where the fault occurred. For circuits used to provide essential services which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel's safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

6.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested. An approved copy of the details required by 1.2.5 and 1.2.6 is to be retained on board and made available to the Surveyor on request.

6.1.5 Short-circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

6.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

6.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with 12.3.5, the protection may be installed at a suitable location in the battery compartment.

6.1.8 Protection may be omitted from the following:
(a) Engine starting battery circuits.
(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

6.1.9 Short-circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition or it is impractical for operational reasons (e.g. within battery compartments), and where the cabling or wiring is installed in a manner such as to minimise the risk of short-circuit.

6.1.10 Overload protection may be omitted from the following:
(a) one line of circuits of the insulated type;
(b) circuits supplying equipment incapable of being overloaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

6.2 Protection against short-circuit

6.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

6.2.2 The rated short-circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in 6.4 and 6.5 respectively.

6.2.3 The prospective fault current is to be calculated for the following set of conditions:
(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements;
(b) a fault of negligible impedance close up to the load side of the protective device.

6.2.4 In the absence of precise data, the prospective fault current may be taken to be:
(a) for alternating current systems at the main switchboard: 10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, X"d,of each generator is known, $\dfrac{\text{f.l.c}}{X''_d\ (\text{p.u.})}$ for each generator and 3 x f.l.c. for motors simultaneously in service;
The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).
(b) battery-fed direct current systems at the battery terminals:
  (i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours, or
  (ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours and,
  (iii) 6 x f.l.c. for motors simultaneously in service, if applicable.

6.3 Protection against overload

6.3.1 Fuses, circuit breakers and other protective devices provided for overload protection are to have fusing/tripping characteristics ensuring the protection of cabling and electrical machinery against overheating resulting from mechanical or electrical overload.

6.3.2 Fuses of a type intended for short-circuit protection only (e.g. fuse links complying with IEC 60269-1, of type “a”) are not to be used for overload protection.

6.4 Protection against earth faults

6.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

6.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

6.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

6.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in 6.4.2 because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

6.5 Circuit-breakers

6.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation (i.e. first half cycle, or time of interruption where an intentional time delay is provided to ensure suitability);

(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;

(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

6.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

6.5.3 The fault ratings considered in 6.5.1 and 6.5.2, are to be assigned on the basis that the device is suitable for further use after fault clearance.

6.5.4 Circuit- breaker selection is, and ratings are, to be in accordance with the relevant requirements of IEC 60092-202: *Electrical installations in ships – System design – Protection*. Alternative methods acceptable to LR of selecting suitable circuit-breakers may be considered.

6.6 Fuses

6.6.1 Fuses for a.c. systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

6.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

6.7 Circuit-breakers requiring back-up by fuse or other device

6.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

6.7.2 The same device may back-up more than one circuit-breaker provided that no essential or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

6.7.3 The combination of back-up device and circuit-breaker is to have a short circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of 6.5.

6.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated short-circuit breaking capacity of the circuit-breaker and;

(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded and;

(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

6.8 Protection of generators

6.8.1 The protective gear required by 6.8.2 and 6.8.3 is to be provided as a minimum.

6.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of short-circuit, overload or under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multiple linked switch with a fuse, complying with 5.3.2, in each insulated pole will be acceptable.

6.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open all insulated poles simultaneously in the event of a short-circuit, an overload or an under-voltage. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of two per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover. A fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

6.8.4 The generator circuit-breaker short-circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

6.8.5 Generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cable between the generator and its circuit breaker, will instantaneously open the circuit breaker and de-excite the generator.

6.8.6 The voltage and time delay settings of the under-voltage release mechanism(s) required by 6.8.2 and 6.8.3 are to be chosen to ensure that the discriminative action required by 6.1.1(a) is maintained.

6.9 Load management

6.9.1 Arrangements are to be made to disconnect automatically, after an appropriate time delay, circuits of the categories noted below, when the generator(s) is/are overloaded; sufficient to ensure the connected generating set(s) is/are not overloaded:

(a) non-essential circuits;
(b) circuits feeding services for habitability, *see* 1.6.2;
(c) in cargo craft, circuits for cargo refrigeration.

Note
For emergency generators *see* 3.2.14, with 3.3.1 or 3.4.1 where applicable.

6.9.2 If required, this load switching may be carried out in one or more stages, in which case the non-essential circuits are to be included in the first group to be disconnected.

6.9.3 An alarm is to be provided to indicate when such switching has taken place.

6.9.4 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

6.9.5 When the electric generating plant is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, it is to be provided with audible and visual alarms for:

(a) Busbar voltage; high or low.
(b) Busbar frequency; low.
(c) Operating of load switching.
(d) Generator cooling air temperature high; closed air circuit machines only.

6.10 Feeder circuits

6.10.1 Isolation and protection of each feeder circuit is to be ensured by a multiple circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with 6.2 and 6.3. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

6.11 Motor circuits

6.11.1 Motors of rating exceeding 0,5 kW and all motors for essential services are to be protected individually against overload and short circuit. For motors which for essential services are duplicated, the overload protection may be replaced by an overload alarm; arrangements for steering unit motors are to comply with 15.1.

6.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

6.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short-circuit protection.

6.11.4 For motors for intermittent service, the characteristics of the arrangements for overload protection are to be chosen in relation to the load factor(s) of the motor(s).

6.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

6.12 Protection of transformers

6.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

6.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

Section 7
Switchgear and control gear assemblies

7.1 General requirements

7.1.1 Switchgear and control gear assemblies and their components are to comply with one of the following standards amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439: *Low voltage switchgear and control gear assemblies*;
(b) IEC 62271-200*: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(c) IEC 60466: *AC insulated-enclosed switchgear for rated voltages above 1 kV and up to and including 38 kV*;
(d) IEC 60255: *Electrical relays*;
(e) acceptable and relevant National Standard.

In addition, the requirements of 7.2 to 7.18 are to be complied with.

7.2 Busbars

7.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/oxidation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the short-circuit withstand strength of the busbar system is to be submitted for consideration when required.

7.2.2 The maximum permissible temperature rise for bare conductors is 45°C. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

7.3 Circuit-breakers

7.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: *Low voltage switchgear and Control gear Pt 2: circuit breakers*;
(b) IEC 60056: *High voltage alternating-current circuit-breakers*;
(c) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuit-breaker are to be submitted for consideration when required.

7.3.2 Circuit-breakers are to be capable of isolation.

7.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

7.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.3.5 Where the means of setting adjustable protection characteristics are not durably marked and locked in position and cannot be visually inspected (e.g. electronic storage), the settings of characteristics are to be recorded and a copy of the records included in the details retained on board, *see* 6.1.4.

7.4 Contactors

7.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature.

(a) IEC 60470: *High-voltage alternating current contactors*.
(b) acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

7.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

7.5 Creepage and clearance distances

7.5.1 The shortest distances between conductive parts and between conductive parts and earth in air or along the surface of an insulating material, are to be suitable for the rated voltage having regard to the nature of the insulating material and the transient over voltages developed by switching and fault conditions. This requirement may be satisfied by subjecting each assembly type to an impulse voltage test in accordance with its constructional Standard or, alternatively, maintaining the minimum distances for bare conductive parts in switchgear and control gear assemblies given in Table 2.7.1.

Table 2.7.1 Minimum clearance distances

Nominal voltage (V)	Minimum clearance distance (mm)			
	Main switchboards		Other switchgear and control gear	
	Type-tested assemblies	Non-type-tested assemblies	Type-tested assemblies	Non-type-tested assemblies
≤ 250	8	15	6	15
>250 to ≤690	8	20	6	20
>690 to 1000	8	25	6	25
<1100	14	14	14	14
<3300	32	55	26	55
<6600	60	90	50	90
<11 000	100	120	80	120
≤15 000	100	160	100	160

NOTE
A minimum clearance distance of 25 mm is required for busbars and other bare conductors in main switchboards.

7.5.2 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in Table 2.7.1.

7.5.3 Switchgear and control gear assemblies for rated voltages up to and including 1 kV are to have creepage distances in accordance with IEC 60092-302, *Electrical installations in ships – Part 302: Low-voltage switchgear and control gear assemblie*s, and Table 2.7.2.

Table 2.7.2 Minimum creepage distances

Nominal voltage (V)	Minimum creepage distance (mm)	
	Main switchboards	Other switchgear and control gear
≤250	20	20
>250 to ≤690	25	25
>690 to 1000	35	35
<3300	48	35
<6600	90	70
<11,000	150	120
≤15,000	150	120

NOTE
A minimum creepage distance of 16 mm is permitted for type-tested assemblies for rated voltages up to and including 1 kV, *see* 7.5.4.

7.5.4 For switchgear and control gear assemblies for rated voltages up to and including 1 kV, a minimum creepage distance of 16 mm is permitted for type-tested assemblies. The type tests are to include verification of the degree of protection, insulation material group and creepage and clearance distances in accordance with IEC 61439-1, *Low-voltage switchgear and control gear assemblies – Part 1: General Rules*.

7.5.5 Switchgear and control gear assemblies for rated voltages above 1 kV are to have creepage distances in accordance with IEC 60092-503, *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*. In the absence of alternative proposals, including supporting design rationale, the distances stated in Table 2.7.2 are to be used, *see also* 1.3.3.

7.5.6 For switchgear and control gear assemblies for rated voltages of 1 kV and above, the type testing stated in Table 2.7.1 is to include verification of the degree of protection in accordance with a relevant International or National Standard.

7.6 Degree of protection

7.6.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

7.6.2 Where switchboards or section boards are required to comply with 5.2.2, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

7.7 Distribution boards

7.7.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure. *See* 7.16.4.

7.8 Earthing of high-voltage switchboards

7.8.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

7.8.2 Protective shutters associated with withdrawable parts are to be clearly marked, e.g. by colour coding, to indicate the incoming and outgoing circuits and bus tie connections.

7.9 Fuses

7.9.1 Fuses are to comply with one of the following standards amended where necessary for ambient temperature.
(a) IEC 60269: *Low-voltage fuses*;
(b) IEC 60282-1: *High voltage fuses Pt 1: Current-limiting fuses*;
(c) acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

7.10 Handrail or handles

7.10.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

7.11 Instruments for alternating current generators

7.11.1 For alternating current generators not operated in parallel, each generator is provided with at least one voltmeter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

7.11.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

7.11.3 For parallelling purposes, two voltmeters, two frequency meters and two synchronising devices, of which one at least is to be a synchroscope or a set of lamps are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other, *see also* 2.2.1.

7.11.4 The indicators and displays required by 7.11.1 to 7.11.3 are to be located and arranged such that they may be viewed at a single operating position. Where manual paralleling is provided, it is to be possible to adjust voltage and frequency at this position.

7.11.5 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

7.12 Instrument scales

7.12.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

7.12.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

7.12.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

7.12.4 Where the indications provided by the instrumentation required by 7.11 are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

7.12.5 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

7.13 Labels

7.13.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

7.14 Protection

7.14.1 For details of the electrical protection required of switchgear and control gear, *see* Section 6.

7.15 Wiring

7.15.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

7.16 Position of switchboards

7.16.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

7.16.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

7.16.3 The spaces defined in 7.16.1 and 7.16.2 are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

7.16.4 So far as practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions, *see* Pt 15, Ch 2,2.4.

7.16.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271-200 and qualified for classification **IAC** (internal arc classification).

7.17 Switchboard auxiliary power supplies

7.17.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

7.18 Testing

7.18.1 Tests in accordance with 7.18.2 to 7.18.4 are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer.

7.18.2 A high voltage test, *see* Section 21.

7.18.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

7.18.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

7.18.5 For switchgear and control gear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200 and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

7.19 Disconnectors and switch-disconnectors

7.19.1 Disconnectors, switch-disconnectors and their components are to comply with one of the following standards, amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 60947-3: *Low voltage switchgear and control gear Part 3: switches, disconnectors, switch-disconnectors and fuse combination units*.
(b) IEC 60129: *Alternating current disconnectors (isolators) and earthing switches*.
(c) Acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

■ *Section 8*
Protection of personnel from hazards resulting from electric arcs within electrical equipment assemblies and enclosures

8.1 General

8.1.1 An assessment is to be carried out in accordance with 8.2.1 for all electrical equipment within which an arcing fault could occur, such as:

- harmonic filters;
- motor starter panels;
- semiconductor converters;
- switchboards, section boards and distribution boards; or
- transformers.

8.2 Hazard identification and assessment

8.2.1 An assessment is to be carried out to identify the hazards and their consequences for personnel resulting from electric arcs within the electrical equipment identified in 8.1.1. The purpose of the assessment is to demonstrate that the design incorporates adequate measures to reduce the risk of injury to personnel should an arcing fault occur within the electrical equipment, and that this will help to ensure both personnel and ship safety. Details of the following are to be submitted:

(a) each task to be performed, e.g. switching, equipment maintenance, instrument observation or cleaning;
(b) the hazards to personnel that could result from an electric arc occurring during each task, and the hazards to personnel that could result from the electric arc;
(c) the methods to be used to help to prevent electric arcs; and
(d) the methods to be used to protect personnel from hazards resulting from electric arcs within electrical equipment.

8.3 Calculations to be submitted

8.3.1 The following calculations are to be conducted and used in the hazard identification and assessment:

(a) Calculations of the maximum current that would flow through an electric arc between each conductor and its adjacent conductor, and between each conductor and the exposed conductive parts of the enclosure, in the case of an arcing fault;
(b) The maximum incident energy at the intended working distance in the case of an arcing fault; and
(c) The distance from each conductor at which the incident energy would be 5 Joules (1,2 calories) per centimetre squared in the case of an arcing fault when the enclosure door is open.

These calculations may be made in accordance with a relevant Standard acceptable to LR, for example, IEEE Standard 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*.

8.4 Testing and trials

8.4.1 It is to be demonstrated that, where provided, arrangements to detect arcing faults function correctly.

Section 9
Rotating machines

9.1 General requirements

9.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this Section.

9.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also* 1.4.

9.1.3 Shafts for rotating machines are to be forged or rolled and are to comply with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

9.1.4 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

9.1.5 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034: *Rotating electrical machines*, Part 14.

9.1.6 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum craft inclinations defined by 1.10 and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

9.1.7 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

9.1.8 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short-circuit at their terminals without damage.

9.2 Rating

9.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in 9.3 being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in 9.3.

9.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

9.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

9.3 Temperature rise

9.3.1 The limits of temperature rise specified in Table 2.9.1, are based on the cooling air temperature and cooling water temperature given in 1.9.

9.3.2 If it is known that the temperature of cooling medium exceeds the values given in 1.9 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

9.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in 1.9 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in 1.9 up to a maximum of 15°C.

9.4 Generator control

9.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distributing system should there be a failure of the voltage regulating system resulting in a high voltage.

9.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no load voltage.

9.4.3 Generators, and their excitation systems, when operating at rated speed and voltage on no-load are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds.

9.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off.

9.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes.

Table 2.9.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C						
Part of machine	Method of temperature measurement	Insulation class				
		A	E	B	F	H
1. (a) a.c. windings of machines having output of 5000 kVA or more	ETD R	55 50	— —	75 70	95 90	115 110
(b) a.c. windings of machines having output of less than 5000 kVA	ETD R	55 50	— 65	80 70	100 95	115 110
2. Windings of armatures having commutators	R T	50 40	65 55	70 60	95 75	115 95
3. Field windings of a.c. and d.c. machines having d.c. excitation other than those in item 4	R T	50 40	65 55	70 60	95 75	115 95
4. (a) Field windings of synchronous machines with cylindrical rotors having d.c. excitation	R	—	—	80	100	125
(b) Stationery field windings of d.c. machines having more than one layer	R T	50 40	65 55	70 60	95 75	115 95
(c) Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
(d) Single-layer windings of a.c. and d.c. machines with exposed bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5. Permanently short-circuited insulated windings	T	50	65	70	90	115
6. Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7. Magnetic cores and other parts not in contact with windings	T					
8. Magnetic cores and other parts in contact with windings	T	50	65	70	90	110
9. Commutators and slip-rings open and enclosed	T	50	60	70	80	90

NOTES
1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in Table 2.9.1 shall be increased by 10°C provided the inlet water temperature does not exceed the values given in 1.9.
2. T = thermometer method
   R = resistance method
   ETD = embedded temperature detector
3. Temperature rise measurements are to use the resistance method whenever practicable.
4. The ETD method may only be used when the ETDs are located between coil sides in the slot.

9.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

9.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than 5 per cent of the rated kVA output of the largest machines.

9.5 Overloads

9.5.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) **Generators**. An excess current of 50 per cent for 15 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The forgoing does not apply to the overload torque capacity of the prime mover.

(b) **Motors**. At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

9.6 Machine enclosure

9.6.1 Where water cooled heat exchangers are used in the machine cooling circuit there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the machine.

9.6.2 An alarm is to be provided to indicate high cooling water temperature.

9.7 Direct current machines

9.7.1 The final running position of brushgear is to be clearly and permanently marked.

9.7.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

9.8 Survey and testing

9.8.1 On machines for essential services tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded.

9.8.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered. For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

9.8.3 A high voltage test, in accordance with Section 21, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals each phase is to be tested separately.

9.8.4 An impulse test is to be carried out on the coils of high voltage machines in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

V_{peak} = 2,45V

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of inter-turn insulation will be considered.

■ *Section 10* Converter equipment

10.1 Transformers

10.1.1 Paragraphs 10.1.2 to 10.1.11 apply to transformers rated for 5 kVA upwards.

10.1.2 Transformers are to comply with the requirements of IEC 60076: *Power transformers*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.9.

10.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

10.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in 1.9, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:
- insulation of Class A – 50°C
- insulation of Class E – 60°C
- insulation of Class B – 70°C
- insulation of Class F – 90°C
- insulation of Class H – 110°C

(b) For liquid filled transformers:
- 50°C – where air provides cooling of the fluid
- 65°C – where water provides cooling of the fluid.

10.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

10.1.6 The inherent regulation of transformers at their rated output is to be such that the total voltage drop to any point in the installation does not exceed that allowed by 1.8.

10.1.7 Transformers, except those for motor starting, are to be double wound.

10.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to

contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

10.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

10.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

10.1.11 Where water cooled heat exchangers are used in transformer cooling circuits, there is to be provision for the detection of water leakage and the system is to be arranged so as to prevent the entry of water into the transformer.

10.1.12 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests issued by the manufacturer, *see also* 1.4.2 and 1.4.3:
(a) measurement of winding resistances, voltage ratio, impedance voltage, short circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type; and
(d) where evidence of compliance with 10.1.9 is not submitted for consideration, short-circuit withstand on one transformer of each size and type.

10.2 Semiconductor equipment

10.2.1 The requirements of 10.2.2 to 10.2.18 apply to semiconductor equipment rated for 5 kW upwards.

10.2.2 Semiconductor equipment is to comply with the requirements of IEC 60146: *Semiconductor converters*, or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see* 1.9.

10.2.3 Semiconductor static power converter equipment is to be rated for the required duty having regard to peak loads, system transients and overvoltage.

10.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively the load may be automatically reduced to a level commensurate with the cooling available.

10.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

10.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

10.2.7 Cooling fluids are to be non-toxic and of low flammability.

10.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

10.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

10.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

10.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced into the craft's electrical system are within the limits of 1.8.3 or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation.

10.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

10.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

10.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

10.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

10.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of 1.8.

10.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

10.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of 21.1, a temperature rise test, on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also* 1.4.2.

10.3 Uninterruptible power systems

10.3.1 Where uninterruptible power systems (UPS) are required to maintain essential services or provide emergency services, the requirements of this Sub-Section apply. This sub-Section is in addition to the requirements of 10.1 and 10.2 and Section 12, as applicable.

10.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)*, or an acceptable and relevant National or International Standard.

10.3.3 The operation of a UPS is not to depend upon external services.

10.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

10.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

10.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and
- bypass in operation for on-line UPS units.

10.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

10.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with 12.3.5. Ventilation arrangements in accordance with IEC 62040: *Uninterruptible power systems (UPS),* or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements of 12.5.10.

10.3.9 Output power is to be maintained for the duration required for the connected equipment.

10.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see* 1.5.

10.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries while maintaining the output supply to the load equipment.

10.3.12 Tests at the manufacturer's works are to include such tests necessary to demonstrate the suitability of a UPS unit for its intended duty and location. This is expected to include as a minimum the following tests:

- a temperature rise test and battery capacity test on one of each size and type of UPS;
- the high voltage test of 20.1;
- a ventilation rate test; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also* 1.4.2.

10.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

■ *Section 11* Electrical cables and busbar trunking systems (busways)

11.1 General

11.1.1 The requirements of 11.1 to 11.16 apply to all electric cables for fixed wiring unless otherwise exempted. The requirements of 11.16 apply to busbar trunking systems (busways) where they are used in place of electric cables.

11.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the relevant IEC Standard stated in Table 2.11.1 or an acceptable and relevant National Standard.

11.1.3 Electric cables for electric propulsion systems are to be Type Approved in accordance with LR's *Type Approval System Test Specification Number 3* or, alternatively, surveyed by the Surveyors during manufacture and testing to assess compliance with the applicable International or National Standards and application of an acceptable quality management system.

11.1.4 Provided that adequate flexibility of the finished cable is assured, conductors of nominal cross-section area 2,5 mm^2 and less need not be stranded.

11.1.5 Electric cables for non-fixed wiring applications are to comply with an acceptable and relevant Standard.

11.1.6 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereafter referred to under the generic name 'protective casings'.

Table 2.11.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092–350	Low-voltage shipboard power cables. General construction and test requirements
Fixed power and control circuits	60092–353	Single and multicore non-radial field power cables with extruded solid insulation for rated voltages 1kV and 3kV
Fixed power circuits	60092–354	Single and three-core power cables with extruded solid insulation for rated voltages 6kV, 10kV and 15kV
Instrumentation, control and communication circuits up to 60 V	60092–375	Shipboard telecommunication cables and radio frequency cables – General instrumentation, control and communication cables
Control circuits up to 250 V	60092–376	Shipboard multicore cables for control circuits
Mineral insulated	60702	Mineral insulated cables with a rated voltage not exceeding 750 V

11.2 Testing

11.2.1 Routine tests, consisting of at least:

(a) measurement of electrical resistance of conductors;

(b) high voltage test, *see also* Section 21;

(c) insulation resistance measurement;

(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of the relevant publication or National Standard referred to in 11.1.2 at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer.

11.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in 11.1.2 and a test report issued by the manufacturer.

11.3 Voltage rating

11.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

11.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

11.4 Operating temperature

11.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10°C higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

11.4.2 The maximum rated conductor temperatures for normal and short-circuit operation, for the insulating materials included within the Standards referred to in 11.1.2 is not to exceed the values stated in Table 2.11.2.

Table 2.11.2 Maximum rated conductor temperature

Type of Insulating compound	Maximum rated conductor temperature °C	
	Normal operation	Short-circuit
Thermoplastics:		
• Based upon polyvinyl chloride or co-polymer of vinyl chloride and vinyl acetate	70	150
Elastomeric or thermosetting:		
• Ethylene-propylene rubber or similar (EPM or EPDM)	90	250
• High modulus or hard grade ethylene propylene rubber	90	250
• Cross-linked polyethylene	90	250
• Ethylene-propylene rubber or similar (EPM or EPDM) halogen-free	90	250
• High modulus or hard grade halogen-free ethylene propylene rubber	90	250
• Halogen-free cross-linked polyethylene	90	250
• Cross-linked polyolefin material for halogen-free cables	90	250
• Silicon rubber	95	350
• Halogen-free silicone rubber	95	350

11.4.3 Electric cables constructed of an insulating material not included in Table 2.11.2 are to be rated in accordance with the National Standard chosen in compliance with 11.1.2.

11.5 Construction

11.5.1 Electric cables are to be at least of a flame-retardant type. Compliance with IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1kW pre-mixed flame*, will be acceptable.

11.5.2 Exemption from the requirements of 11.5.1 for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

11.5.3 Where electric cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and to comply with the performance requirements of the appropriate part of IEC 60331:*Tests for electric cables under fire conditions - Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:
IEC 60331-21*: Procedures and requirements – Cables of rated voltage up to and including 0.6/1.0kV;*
IEC 60331-23: *Procedures and requirements – Electric data cables;*
IEC 60331-25: *Procedures and requirements – Optical fibre cables*.

11.5.4 Where electric cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour they are to have the conductor insulating materials enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

11.5.5 Where it is required that the construction of electrical cables includes metallic sheaths, armouring or braids are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion, *see also* 11.8.7 and 11.8.8.

11.5.6 Where cables are installed in an area where contamination by oil is likely to occur, the oversheath is to be of an enhanced oil resistance grade.

11.5.7 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured the armour is to be of a non-magnetic material.

11.5.8 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short-circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short-circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short circuit current.

11.5.9 All high voltage electric cables are to be readily identified by suitable marking.

11.6 Conductor size

11.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in 11.7 may be applied as required.

11.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short-circuit conditions, the maximum rated conductor temperature for short-circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short-circuit current.

11.6.3 The cable current ratings given in Tables 2.11.3 and 2.11.4 are based on the maximum rated conductor temperatures given in Table 2.11.2. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short-circuit temperature limits, other than those given in Table 2.11.4, may be applied using the data provided in:

- IEC 60724: *Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*; or
- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV*).

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

11.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in 1.8 be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

11.6.5 The size of earth conductors is to comply with 1.12.8.

11.6.6 The cross-sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cable's maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see* 11.7.4.

11.7 Correction factors for cable current rating

11.7.1 The correction factors of 11.7.2 to 11.7.5 provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

11.7.2 Bunching of cables. Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

11.7.3 Ambient temperature. The current ratings of Table 2.11.3 are based on an ambient temperature of 45°C. For other values of ambient temperature the correction factors shown in Table 2.11.5 are to be applied.

Table 2.11.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross-section (mm^2)	Continuous r.m.s current rating, in amperes								
	Thermoplastic (70°C)			Elastomeric (90°C)			Elastomeric or thermosetting, based on silicon rubber (95°C)		
	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core	Single core	2 core	3 or 4 core
0,75	10	8	7	15	13	11	17	14	12
1	12	10	8	18	15	13	20	17	14
1,25	13	11	9	21	18	14	23	20	16
1,5	15	13	11	23	20	16	26	22	18
2	18	15	12	28	24	19	31	26	22
2,5	21	18	15	40	26	21	32	27	22
3,5	26	22	18	37	32	26	39	33	28
4	29	25	20	51	34	28	43	37	30
5,5	35	30	24	49	42	35	52	44	37
6	37	31	26	52	44	36	55	47	39
8	44	37	31	62	53	44	66	56	46
10	51	43	36	72	61	50	76	65	53
14	62	53	44	88	75	62	94	80	66
16	68	58	48	96	82	67	102	87	71
22	83	70	58	117	100	82	124	106	87
25	90	77	63	127	108	89	135	115	95
30	101	85	70	142	121	100	151	128	106
35	111	94	78	157	133	110	166	141	116
38	117	99	82	165	140	116	175	149	122
50	138	117	97	196	167	137	208	177	146
60	155	132	109	220	187	154	233	198	163
70	171	145	120	242	206	169	256	218	179
80	186	158	130	263	224	184	278	237	195
95	207	176	145	293	249	205	310	264	217
100	213	181	149	302	257	212	320	272	224
120	239	203	167	339	288	237	359	305	251
125	245	209	172	348	295	243	368	313	258
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
200	329	280	230	466	396	326	494	420	346
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

11.7.4 Short time duty. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant *T* in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1{,}12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-loads less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

T = $0{,}245d^{1{,}35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current, in minutes

t_p = the intermittent period in minutes, i.e. the total period of load and no-load before the cycle is repeated.

11.7.5 Diversity. Where cables are used to supply two or more final sub-circuits account may be taken of any diversity factors which may apply, *see* 5.6.

11.8 Installation of electric cables

11.8.1 Electric cable runs are to be as far as practicable fixed in straight lines and in accessible positions.

11.8.2 Bends in fixed electric cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in Table 2.11.6.

11.8.3 The installation of electric cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. The internal radius of the loop is to be at least 12 times the external diameter of the cable.

Table 2.11.4 Electric cable current ratings, r.m.s. short-circuit current

Nominal cross-section (mm^2)	Fault current (kA) at 150°C			Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration	1 s duration	0,5 s duration	0,1 s duration
0,75	0,1	0,1	0,3	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,3	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,1	0,2	0,4	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,2	0,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,2	0,3	0,7	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,3	0,4	0,9	0,4	0,5	1,1	0,4	0,6	1,4
3,5	0,4	0,5	1,2	0,5	0,7	1,6	0,6	0,8	1,9
4	0,4	0,6	1,4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,6	0,8	1,9	0,8	1,1	2,5	0,9	1,3	3,0
6	0,7	0,9	2,1	0,9	1,2	2,7	1,0	1,5	3,2
8	0,9	1,2	2,8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,1	1,5	3,5	1,4	2,0	4,5	1,7	2,4	5,4
14	1,5	2,2	4,8	2,0	2,8	6,3	2,4	3,4	7,6
16	1,7	2,5	5,5	2,3	3,2	7,2	2,7	3,9	8,7
22	2,4	3,4	7,6	3,1	4,5	10,0	3,8	5,3	11,9
25	2,7	3,9	8,6	3,6	5,1	11,3	4,3	6,0	13,5
30	3,3	4,6	10,4	4,3	6,1	13,6	5,1	7,3	16,2
35	3,8	5,4	12,1	5,0	7,1	15,8	6,0	8,5	18,9
38	4,1	5,9	13,1	5,4	7,7	17,2	6,5	9,2	20,6
50	5,5	7,7	17,3	7,2	10,1	22,6	8,6	12,1	27,1
60	6,5	9,3	20,7	8,6	12,1	27,1	10,3	14,5	32,5
70	7,6	10,8	24,2	10,0	14,2	31,7	12,0	16,9	37,9
80	8,7	12,3	37,6	11,4	16,2	36,2	13,7	19,4	43,3
95	10,4	14,7	32,8	13,6	19,2	43,0	16,3	23,0	51,4
100	10,9	15,4	34,5	14,3	20,2	45,2	17,1	24,2	54,1
120	13,1	18,5	41,4	17,2	24,3	54,3	20,5	29,0	64,9
125	13,6	19,3	43,1	17,9	25,3	56,6	21,4	30,2	67,6
150	16,4	23,2	51,8	21,5	30,4	67,9	25,7	36,3	81,2
185	20,2	28,6	63,9	26,5	37,4	83,7	31,7	44,8	100,1
200	21,8	30,9	69,0	28,6	40,5	90,5	34,2	48,4	108,2
240	26,2	37,0	82,8	34,3	48,6	108,6	41,1	58,1	129,9
300	32,7	46,3	103,6	42,9	60,7	135,7	51,3	72,6	162,3

Table 2.11.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Thermoplastic (70°C)	1,18	1,10	1,00	0,89	0,77	0,63	—	—	—	—	—
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	—
Elastomeric or thermosetting, based on silicone rubber (90°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

Table 2.11.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm > 25 mm	4*D* 6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core	Any	Any	12*D*
– multicore	Any	Any	9*D*

11.8.4 Electric cables for essential and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude their being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

11.8.5 Electric cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

11.8.6 Electric cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

11.8.7 Cables having an exposed metallic screen, braid or armour are to be installed in such a manner that galvanic corrosion by contact with other metals is prevented. Sufficient measures are also to be taken to prevent damage to exposed galvanised coatings during installation.

11.8.8 Protection is to be provided for cable oversheaths in areas where cables are likely to be exposed to damaging substances under normal circumstances or areas where the spillage or release of harmful substances is likely.

11.8.9 Electric cables are to be as far as practicable installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

11.8.10 Where electric cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332:*Tests on electric cables under fire conditions, Part 3-22, Test for vertical flame spread of vertically-mounted bunched wires or cables – Category A*, and are installed in the same configuration(s) as are used for the test(s). If the cables are not so installed, information is to be submitted to satisfactorily demonstrate that suitable measures have been taken to ensure that an equivalent limit of fire propagation will be achieved for the configurations to be used. Particular attention is to be given to cables in:

- atria or equivalent spaces; and
- vertical runs in trunks and other restricted spaces.

In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2.

11.8.11 Electric cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

11.8.12 Where electric cables are installed in refrigerated spaces they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

11.8.13 All metal coverings of electric cables are to be earthed in accordance with 1.12.

11.8.14 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;

(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

11.8.15 High voltage electric cables are not to be run in the open through accommodation spaces.

11.8.16 High voltage electric cables are to be segregated as far as is practicable from electric cables operating at lower voltages.

11.8.17 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of 11.14 are to be complied with, *see also* 11.5.7.

11.8.18 Electric cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary, the cables are to be protected in accordance with the requirements of 11.9.

11.8.19 Electric cables, with the exception of those for portable appliances and those installed in protective casings, are to be fixed securely in accordance with the requirements of 11.10.

11.8.20 Where electric cables penetrate bulkheads and decks, the requirements of 11.11 are to be complied with.

11.8.21 Where electric cables are installed in protective casings, the requirements of 11.12 are to be complied with.

11.9 Mechanical protection of cables

11.9.1 Where electric cables are exposed to risk of mechanical damage they are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

11.9.2 Electric cables installed in spaces where there is exceptional risk of mechanical damage such as holds, storage spaces, cargo spaces, etc., are to be suitably protected by metallic protective casings, even when armoured, unless the craft's structure affords adequate protection.

11.9.3 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with 1.12.

11.10 Cable support systems

11.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the craft's structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads, etc., *see* 11.8.4.

11.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the craft's structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g., where located in areas subject to impact by sea-water.

11.10.3 The distances between the points at which the cable is supported (e.g., distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e., size and rigidity) and the probability of vibration and are to be generally in accordance with those given in Table 2.11.7.

Table 2.11.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
Exceeding	Not exceeding		
mm	mm	mm	mm
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

11.10.4 Where the cables are laid on top of their support system, the spacings of fixings may be increased beyond those given in Table 2.11.7, but should take account of the probability of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to impact by sea-water.

11.10.5 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short-circuit current.

11.11 Penetration of bulkheads and decks by cables

11.11.1 Where electric cables pass through watertight, fire insulated or gas tight bulkheads, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

11.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

11.11.3 Electric cables passing through decks are to be protected by deck tubes or ducts.

11.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

11.12 Installation of electric cables in protective casings

11.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric cables.

11.12.2 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

11.12.3 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see* 11.8.2.

11.12.4 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

11.12.5 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

11.12.6 Expansion joints are to be provided in protective casings where necessary.

11.12.7 Protective casings containing high voltage electric cables are not to contain other electric cables and are to be clearly identified, defining their function and voltage.

11.13 Non-metallic cable support systems, protective casings and fixings

11.13.1 Where it is proposed to use non-metallic cable support systems, protective casings or fixings, the additional requirements of this sub-Section apply. For high voltage installations, metallic protective casings are required where 11.8.14(b) applies.

11.13.2 Non-metallic cable support systems and protective casings are to be installed in accordance with the manufacturer's recommendations. The support systems and protective casings are to have been tested in accordance with an acceptable test procedure for:
(a) ambient operating temperatures;
(b) safe working load;
(c) impact resistance;
(d) flame retardancy;
(e) smoke and toxicity; and
(f) use in explosive gas atmospheres or in the presence of combustible dusts, electrical conductivity;
with satisfactory results.

11.13.3 Non-metallic cable support systems, protective casings and fixings installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

11.13.4 Where the cable support system, protective casing or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided such that, in the event of a fire or failure, the cable support system, protective casing and the affixed cables are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

11.13.5 The load on non-metallic cable support systems or protective casings is not to exceed the tested safe working load.

11.13.6 When a cable support system or protective casing is secured by means of clips or straps manufactured from a material other than metal the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m and, for non-metallic cable support systems or protective casing, that used during safe working load testing.

11.13.7 Non-metallic fixings are to be flame retardant in accordance with the requirements of IEC 60092-101, or an alternative, relevant National or International Standard.

11.14 Single core electric cables for alternating current

11.14.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

11.14.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

11.14.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

11.14.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

11.14.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

11.15 Electric cable ends

11.15.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see* 1.11.7), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

11.15.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

11.15.3 Soldered sockets may be used in conjunction with non-corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160°C.

11.15.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

11.15.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

11.15.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating.

11.15.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

11.16 Joints and branch circuits in cable systems

11.16.1 If a joint is necessary it is to be carried out so that all conductors are adequately secured, insulated and protected from atmospheric action. The flame retardant properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current carrying capacity of the cable is not to be impaired.

11.16.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

11.16.3 Cables of a fire-resistant type, *see* 11.5.3, are to be installed so that they are continuous throughout their length, without any joints or tappings.

11.17 Busbar trunking systems (bustrunks)

11.17.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of 11.17.2 to 11.17.6, in addition to the applicable requirements in Section 7.

11.17.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

11.17.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

11.17.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in 1.10 for essential electrical equipment.

11.17.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the craft's structure.

11.17.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

■ *Section 12* Batteries

12.1 General

12.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve-regulated sealed type.

12.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

12.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

12.2 Construction

12.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

12.3 Location

12.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

12.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with 12.3.1, or may be installed within a well ventilated machinery or similar space.

12.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

12.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of 12.3.1, 12.3.2 or 12.3.3.

12.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of 12.5.10 and the charging requirements of 12.6.4 and 12.6.5 are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

12.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

12.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects they are to be suitably protected.

12.3.8 Batteries installed in crew and passenger cabins, together with their associated corridors, are to be of the hermetically sealed type.

12.3.9 A permanent notice prohibiting smoking and the use of naked lights or equipment, capable of creating a source of ignition, is to be prominently displayed adjacent to the entrances of all compartments containing batteries.

12.3.10 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with 12.3.1, the compartment ventilation exhaust ducts and zones within a 1,5 m radius of the ventilation outlet(s). Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with IEC 60079: *Electrical apparatus for explosive gas atmospheres*, or an acceptable and relevant National Standard.

12.3.11 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also* 1.5.3.

12.4 Installation

12.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are suitably secured to move with the craft's motion. For high speed craft, the securing arrangements for batteries are to, as far as practicable, prevent excessive movement during the accelerations due to grounding or collision.

12.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

12.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

12.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

12.4.5 High speed craft are to be provided with an alarm to indicate that immediate action is required in the event of thermal runaway of any nickel cadmium battery.

12.5 Ventilation

12.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas.

12.5.2 Where a battery compartment ventilator is required to be fitted with a closing device in accordance with Vol 3, Pt 3, Ch 4,11.4.1, a warning notice clearly stating the purpose of the closing device, for example, 'This closing device is to be kept open and only closed in the event of a fire or flooding – Explosive gas atmosphere', is to be provided at the closing device to mitigate the possibility of inadvertent closing of the ventilator. Furthermore, means to lock battery compartment ventilators in the open position are to be provided.

12.5.3 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

12.5.4 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

12.5.5 Mechanical exhaust ventilation complying with 12.5.9 is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW and also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

12.5.6 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which 12.3.2, 12.3.3 and 12.3.5 refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

12.5.7 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

12.5.8 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic-impellers are to be of an anti-static material.

12.5.9 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

12.5.10 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$Q = 110 I n$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

12.5.11 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in 12.5.10.

12.6 Charging facilities

12.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

12.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

12.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

12.6.4 Where valve-regulated sealed batteries are installed, the charging facilities are to incorporate independent means such as overvoltage protection to prevent gas evolution in excess of the manufacturer's design quantity.

12.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

12.7 Recording of batteries for emergency and essential services

12.7.1 A schedule of batteries fitted for use for essential and emergency services is to be compiled and maintained.

12.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also* 1.5.3.

12.7.3 When additions or alterations are proposed to the existing batteries for essential and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with 1.5.2.

12.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

12.8 Cables

12.8.1 Where it is impracticable to provide electrical protective devices for certain cables supplied from batteries, e.g. within battery compartments and in engine starting circuits, unprotected cable runs are to be kept as short as possible and special precautions should be taken to minimise risk of faults, e.g., use of single core cables with additional sleeve over the insulation of each core, with shrouded terminals.

■ *Section 13* Equipment – Heating, lighting and accessories

13.1 Heating and cooking equipment

13.1.1 The construction of heaters is to give a degree of protection according to IEC 60529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

13.1.2 Heating elements are to be suitably guarded.

13.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

13.2 Lighting – General

13.2.1 Lampholders are to be constructed of flame retarding non-hygroscopic materials.

13.2.2 Lighting fittings are to be so arranged as to prevent temperature rises which overheat or damage surrounding materials. They must not impair the integrity of fire divisions.

13.3 Incandescent lighting

13.3.1 Tungsten filament lamps and lampholders are to be in accordance with Table 2.13.1.

Table 2.13.1 Lamps and lampholders

Designation	Maximum lamp rating		Maximum lampholder current, A
	Voltage, V	Power, W	
Screw cap lamps			
E40	250	3000	16
E27	250	200	4
E14	250	15	2
E10	24	—	2
Bayonet cap lamps			
B22	250	200	4
B15d	250	15	2
B15s	55	15	2
Tubular fluorescent lamps			
G13	250	80	—
G5	250	13	—

13.3.2 Lampholders of type E40 are to be provided with a means of locking the lamp in the lampholder.

13.4 Fluorescent lighting

13.4.1 Fluorescent lamps and lampholders are to be in accordance with Table 2.13.1.

13.4.2 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

13.4.3 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

13.5 Discharge lighting

13.5.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

13.6 Socket outlets and plugs

13.6.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30°C. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

13.6.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.

13.6.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

13.6.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

13.7 Enclosures

13.7.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

■ *Section 14* Electrical equipment for use in explosive atmospheres

14.1 General

14.1.1 Electrical equipment is not to be installed in areas where an explosive atmosphere may be present, except where necessary for operational and/or safety purposes, when the equipment is to be of a certified safe type as listed below and details of the equipment and installation are to be submitted for consideration. The construction and type testing is to be in accordance with IEC 60079: *Electrical Equipment for Explosive Gas Atmospheres* or an acceptable and relevant National Standard.

Intrinsically safe	–	Ex 'i'
Increased safety	–	Ex 'e'
Flameproof	–	Ex 'd'
Pressurised enclosure	–	Ex 'p'
Powder filled	–	Ex 'q'
Encapsulated	–	Ex 'm'

14.1.2 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, e.g., areas containing flammable gas or vapour and/or combustible dust, are, to comply with the relevant requirements of Pt 6, Ch 2,13 of the *Rules and Regulations for the Classification of Ships*.

14.1.3 Where cables are installed in hazardous areas, precautions are to be taken against risks being introduced in the event of an electrical fault.

14.1.4 For craft with spaces for carrying vehicles with fuel in their tanks for their own propulsion, the following requirements are also applicable:

(a) electrical equipment fitted within a height of 45 cm above the vehicle deck, or any platform on which vehicles are carried, or within the exhaust ventilation trunking for the space, is to be of a safe type;

(b) electrical equipment situated elsewhere within the space is to have an enclosure of ingress protection rating of at least IP55, if not of a safe type. (*See* IEC 60529: *Classification of Degrees of Protection Provided by Enclosures*). Smoke and gas detector heads are exempt from this requirement.

■ *Section 15* Navigation and manoeuvring systems

15.1 Steering systems

15.1.1 The requirements of 15.1.2 to 15.1.7 are to be read in conjunction with those in Pt 14, Ch 1.

15.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously are to be provided for each electric or electrohydraulic steering unit arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard. For high speed craft, one of these circuits is to be fed either from the emergency source of electric power or from an independent power source located in such a position as to be unaffected by fire or flooding affecting the main source of power. *See also* Pt 14, Ch 1,6.

15.1.3 The main and auxiliary steering unit motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

15.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering unit.

15.1.5 Only short circuit protection is to be provided for each main and auxiliary steering unit motor circuit.

15.1.6 In craft of less than 1600 gross tonnage, if an auxiliary steering unit is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering unit may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in 15.1.5 for such a motor primarily intended for other services.

15.1.7 Each main and auxiliary steering unit electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering unit compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering unit power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

15.2 Thruster systems for manoeuvring

15.2.1 Where a tunnel or athwartship thruster is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any essential services.

15.2.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the craft, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

15.2.3 The thruster electric motor is not to be disconnected as part of a load management switching operation.

15.3 Navigation lights

15.3.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected directly or through transformers to the emergency source of electrical power in compliance with, for passenger craft, 3.2.7(b)(i) and (ii) and 3.2.9(a) or, for cargo craft, 3.3.8(b)(i) and (ii) and 3.3.8(a). An alarm is to be activated in the event of failure of a power supply from the distribution board.

15.3.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

15.3.3 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power.

15.3.4 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g., a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to pilot boats, fishing boats and similar small vessels.

15.3.5 For navigation lights using light emitting diodes (consisting of multiple light sources) means to ensure that the overall luminous intensity of the navigation light is sufficient are to be provided in addition to the alarm to indicate the complete loss of the navigation light illumination required by 15.3.4. For replacement navigation lights, *see* 1.5.5.

15.3.6 To satisfy 15.3.5, an audible and visual alarm is to be activated to notify the Officer of the Watch that the luminous intensity of the light reduces below the level required by the IMO Convention on the International Regulations for Preventing Collisions at Sea. Alternative measures to ensure continuing acceptable performance of navigation lights using light emitting diodes may be considered that are in accordance with:

- IMO Res. MSC.253(83), *Performance Standards for Navigation Lights, Navigation Light Controllers and associated Equipment*, and
- EN 14744, *Inland navigation vessels and sea-going vessels – Navigation light*, or a relevant National or International Standard.

Where alternative measures are proposed that require periodic verification by personnel of the luminous intensity of navigation lights using light emitting diodes, details of the inspection implementation in the ships safety management system and acceptance by the National Administration requirements are to be submitted for consideration.

15.3.7 Navigation light power supply units installed to convert, control and/or monitor the distribution board power supply required by 15.3.1 above for connection to the light source(s) (e.g. for LED type navigation lights) are, in the event of a short-circuit on the unit output, are to disconnect or limit the supply to prevent further damage and activate an alarm in the event of a short-circuit on the unit output side.

15.3.8 Navigation light power supply units are to be self-checking, detecting failures of the unit itself and activating an alarm. These are to include:

- detection of system lock-ups (program hangs);
- means to detect whether navigation light switching command input circuits or links; and
- means to detect failure of the navigation light monitoring arrangements required to provide the alarms required by 15.3.4 and 15.3.5, as applicable.

15.3.9 The navigation light power supply failure alarms required by 15.3.1 are not to be displayed as a group alarm. Other navigation light alarms may be grouped for each navigation light where means are provided for personnel to determine the cause of the alarm. Activation of more than one of the navigation light alarms as a result of a single failure is to be prevented.

15.3.10 Any statutory requirements of the country of registration are to be complied with and may be accepted as an alternative to the above.

15.4 Navigational aids

15.4.1 Navigational aids as required by statutory regulations are to be fed from the emergency source of electrical power. *See also* 3.2.7(d)(i) and 3.3.7(d)(i).

15.5 Stabilisation

15.5.1 Where the stabilisation of a craft is essentially dependent upon a single device which in turn is dependent upon a continuous supply of electrical power, the supply arrangements are to comply with 5.2.3.

15.5.2 Where such systems are not dependent upon the continuous availability of electrical power, but one or more alternative systems not dependent upon the electrical supply are installed, a single circuit may be provided, with the protection and alarms required by 5.2.3.

■ *Section 16*
Electric propulsion

16.1 General

16.1.1 Where electric propulsion is proposed, details are to be submitted and the arrangements will be subject to special consideration.

Section 17
Fire safety systems

17.1 Fire detection and alarm systems

17.1.1 Fire detection and alarm systems are to be in accordance with Chapter 9 of the Fire Safety Systems Code (FSS Code) and 17.1.2 to 17.1.19.

17.1.2 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by 3.2, 3.3 or 3.4, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with 11.6.4.

17.1.3 Automatic changeover facilities in accordance with 5.3.5 are to be located in, or adjacent to, the main fire control panel. Power supply changeover is to be achieved without adverse effect. Failure of any power supply is to operate an audible and visual alarm. *See also* 1.15 and 1.16.

17.1.4 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

17.1.5 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and fire alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

17.1.6 For machinery spaces the requirements of Ch 1,2.8 are applicable.

17.1.7 Fire detection systems within the accommodation spaces and cabin balconies are, in addition to the requirements of Chapter 1, as applicable, to comply with 17.1.8 to 17.1.19.

17.1.8 The fire control panel is to be located on the navigating bridge or in a central fire control station and may form part of that panel specified in Ch 1,2.8.2. In passenger craft carrying more than 36 passengers, the fire control panel is to be located in the continuously manned central control station.

17.1.9 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. For craft required to comply with the HSC Code, there is to be no time delay for the audible alarms in crew accommodation areas, following initiation of an audible and visual alarm at the control panel and indicating units, when all the control stations are unattended. This alarm sounder system need not be an integral part of the detection system.

17.1.10 In yachts, the fixed fire detection and fire alarm system is to be capable of remotely and individually identifying each detector and manually operated call point. On other craft, indicating units are to denote, as a minimum, the section in which a detector or manually operated call point has operated. At least one unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

17.1.11 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section and, for yachts, each detector and manually operated call point.

17.1.12 Where the fire detection system does not include means of remotely identifying each detector and manually operated call point individually no section covering more than one deck within accommodation, service spaces and control stations is normally to be permitted except a section which covers an enclosed stairway. The number of enclosed spaces in each section are to be limited to the minimum considered necessary in order to avoid delay in identifying the source of fire. In no case are more than fifty spaces permitted in any section.

17.1.13 In passenger craft other than yachts, where the fire detection system does not include means of remotely identifying each detector individually a section of detectors is neither to serve spaces on both sides of the craft nor on more than one deck except when permitted by 17.1.18.

17.1.14 A section of fire detectors and manually operated call points which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

17.1.15 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel. For craft required to comply with the HSC Code, the control panel may be used to activate a paging system, fan stops, closure of fire doors, closure of fire and smoke dampers, and/or a sprinkler system.

17.1.16 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop, individually each detector and manually operated call point served by the circuit, may serve spaces on both sides of the craft and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers an accommodation space, service space and/or control station to include a machinery space of Category A.

17.1.17 A loop circuit of an addressable fire detection system may comprise one or more sections of detectors and manually operated call points. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that if a short-circuit occurs anywhere in the loop, only the affected section of detectors and manually operated call points will be isolated from the control panel. No section of detectors and manually operated call points is in general to include more than 50 detectors.

17.1.18 A section of fire detectors and manually operated call points is not to be situated in more than one main vertical or horizontal fire zone. Additionally, for craft required to comply with the HSC Code, a section of detectors and manually operated call points section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the craft nor on more than one deck, except that:

(a) a section of detectors and manually operated call points may serve spaces on more than one deck if those spaces are located in either the fore or aft end of the craft, or they constitute common spaces occupying several decks, i.e. public spaces, enclosed stairways, etc.

(b) in craft of less than 20 m in breadth, a section of detectors and manually operated call points may serve spaces on both sides of the craft.

17.1.19 The wiring for each section of detectors and manually operated call points in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop. When this is not practical, such as in large public spaces, the part of the loop which by necessity passes through the space for a second time is to be installed at the maximum possible distance from other parts of the loop.

17.2 Automatic sprinkler system

17.2.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

17.2.2 For passenger craft, electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.2.3 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

17.2.4 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

17.3 Fixed water-based local application fire-fighting systems

17.3.1 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power.

17.3.2 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by 3.2, 3.3 or 3.4 and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

17.3.3 Failure of any power supply is to operate an audible and visual alarm. *See also* 1.15 and 1.16.

17.3.4 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Where it is proposed to install local activation means outside of the protected space, details are to be submitted for consideration.

17.3.5 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application, fire-fighting systems and adjacent areas where water may extend, the requirements of 17.3.6 to 17.3.10 apply.

17.3.6 As far as is practicable, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The system pump, its electrical motor and the sea valve if any, may be in a protected space provided that they are outside areas where water or spray may extend.

17.3.7 High voltage equipment and their enclosures are not to be installed in protected areas or adjacent areas. For high voltage generators enclosures which cannot be fully located outside of adjacent areas due to close proximity, a technical justification, including proposed degree of protection ratings that are normally not to be lower that IP54, may be submitted for consideration that demonstrates the overall safety of the installation in the event of system operation.

17.3.8 In addition to the degree of protection requirements of 1.11.1, electrical and electronic equipment enclosures located within protected areas and within adjacent areas are to provide adequate protection in the event of system operation.

17.3.9 To demonstrate compliance with 17.3.8, evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas is to be submitted in accordance with 1.2.12. The evidence is to demonstrate that additional precautions have been taken, where necessary, in respect of:

(a) satisfying 17.3.6 and 17.3.7;
(b) personnel protection against electric shock;
(c) cooling airflow, where necessary, for equipment required to operate during system operation; and
(d) maintenance requirements for equipment before return to operation following system activation.

Any test evidence submitted is to consider the overall installation, including equipment types, system configuration and nozzles and the potential effects of airflows in the protected space.

17.3.10 The evidence required by 17.3.9 is to demonstrate the safe and effective operation of the overall arrangements in the event of system operation. This evidence is to demonstrate that exposure to system spray and/or water:

- cannot result in loss of essential services (e.g. unintended activation of automatic machinery shut-down);
- cannot result in loss of availability of emergency services;
- will not affect the continued safe and effective operation of electrical and electronic equipment required to operate during the required period of system operation;
- does not present additional electrical or fire hazards; and
- would require only identified readily replaceable components to be repaired or replaced.

The installation of electrical and electronic equipment required to provide essential or emergency services in enclosures with a degree of protection less than IP44 within areas exposed to direct spray is to be acceptable to LR, and evidence of suitability is to be submitted accordingly.

17.3.11 Fixed water-based local application fire-fighting system electrically-driven pumps may be shared with:

- equivalent automatic sprinkler systems;
- equivalent main machinery space fire-fighting systems; or
- local fire-fighting systems for deep-fat cooking equipment;

provided that the shared use is accepted by the National Administration as complying with applicable statutory regulations and the arrangements comply with the requirements of 17.3.12 to 17.3.14.

17.3.12 Shared electrically-driven sea-water pumps are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the pumps and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

17.3.13 Failure of a component in the power and control system is not to result in a reduction of the total available pump capacity below that required by any of the areas which the system is required to protect. For equivalent automatic sprinkler systems, a failure is not to prevent automatic release or reduce sprinkler pump capacity by more than 50 per cent.

17.3.14 Where fire-fighting systems share fire-fighting pumps, failure of one system is not to prevent activation of the pumps by any other system.

17.4 Fire pumps

17.4.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

17.4.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

17.5 Refrigerated liquid carbon dioxide systems

17.5.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

17.5.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

17.6 Fire safety stops

17.6.1 In order to limit the fire growth potential in every space of the craft, means for controlling the air supply to the spaces and flammable liquids within the spaces are to be provided.

17.6.2 To control air supply, a means of stopping all forced and induced draught fans, and all ventilation fans serving accommodation spaces, service spaces, control stations and machinery spaces from an easily accessible position outside of the space being served is to be provided. The position is not to be readily cut off in the event of a fire in the spaces served by the fans.

17.6.3 In passenger craft carrying more than 36 passengers, a second means of stopping ventilation fans serving accommodation spaces, service spaces and control stations is to be provided at a position as far apart from the position required by 17.6.2 as is practicable. At both positions, the controls are to be grouped so that all fans can be stopped from either of the two positions.

17.6.4 A second means of stopping ventilation fans serving machinery spaces is to be provided at a position as far apart from the position required by 17.6.2 as is practicable. At both positions the controls are to be grouped so that all fans are operable from either of the two positions. The means for stopping machinery space ventilation fans are to be entirely

separate from the means for stopping fans serving all other spaces.

17.6.5 In passenger craft, the means of stopping machinery ventilation fans required by 17.6.2 is to be located at the central control station which is to have safe access from the open deck. The central control station is to be provided with ventilation fan OFF status indications, together with a means for restarting the ventilation fans.

17.6.6 In passenger craft carrying 36 passengers or more with main laundries, electrically operated fire dampers fitted at the lower end of the laundry exhaust ducts required to comply with relevant statutory regulations are to be fitted with additional remote-control arrangements for shutting off the exhaust fans and supply fans and operating the fire dampers from within the space.

17.6.7 To control flammable liquids, a means of stopping all fuel oil, lubricating oil, hydraulic oil, cargo oil and thermal oil pumps and oil purifiers from outside the spaces being served is to be provided. The position is not to be cut off in the event of a fire.

17.6.8 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire.

17.6.9 Following activation of any fire safety stops, a manual reset is to be provided in order to restart the associated equipment.

17.6.10 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire-resistant type, *see* 11.5.3. *See also* 5.2.1.

17.6.11 High speed craft bridge areas are to be provided with suitable emergency means to:

(a) close ventilation openings and stop ventilating machinery supplying spaces covered by fixed fire-extinguishing systems;
(b) shut off fuel supplies to machinery in main and auxiliary machinery spaces; and
(c) stop main engine(s) and auxiliary machinery.

NOTE

These emergency means are to be sited in conjunction with required fixed fire extinguishing system activation means.

17.6.12 Additionally, Passenger (B) high speed craft are to be provided with the means required by 17.6.11 at one or more alternative stations separate from the bridge area. *See also* Ch 1,2.6.7.

17.7 Fire doors

17.7.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by 3.2. In passenger craft carrying more than 36 passengers an alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15 and 1.16.

17.7.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

17.8 Fire dampers

17.8.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

17.8.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

17.8.3 In passenger craft carrying 36 passenger or more with main laundries, where electrically operated fire dampers are required to comply with relevant statutory regulations to be fitted at the lower end of exhaust ducts from any main laundries, they are to be capable of automatic and remote operation.

17.8.4 For craft required to comply with the HSC Code with galley range exhaust ducts, electrically operated fire dampers fitted in the lower or upper end of the duct are to be remotely operated and, additionally, the fire damper at the lower end of the duct is to be automatically operated.

17.9 Fire-extinguishing media release alarms

17.9.1 Where it is required that alarms be provided to warn of the release of a fire extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by 3.2, 3.3 or 3.4 and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also* 1.15. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15 and 1.16.

17.10 Electrically powered air compressors for breathing air cylinders

17.10.1 In yachts that are 500 gt or more carrying more than 36 passengers where electrically powered air compressors are installed as part of the means required by the National Administration, for recharging breathing apparatus air cylinders for fire-fighter's outfits, the compressors are to be supplied by the main and emergency sources of electrical power. Details of the emergency supply electrical load, supply changeover arrangements and operation under fire conditions are to be submitted for consideration. The arrangements are to be to the satisfaction of the National Administration with which the craft is registered.

Section 18
Crew and passenger emergency safety systems

18.1 Emergency lighting

18.1.1 For the purpose of this Section emergency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name 'emergency lighting'.

18.1.2 Emergency lighting provided in compliance with Section 3 is to be arranged so that a fire or other casualty in the spaces containing the emergency source of electrical power, associated transforming equipment and the emergency lighting switchboard does not render the main lighting system inoperative.

18.1.3 The level of illumination provided by the emergency lighting is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see* 18.4.

18.1.4 The exit(s) from every main compartment occupied by passengers or crew is to be continuously illuminated by an emergency lighting fitting.

18.1.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, e.g., storage-rooms, cold rooms, etc., or they are normally required to be extinguished for operational reasons, e.g., for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to craft crew with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions.

18.1.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

18.1.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

18.2 General emergency alarm system

18.2.1 An electrically operated bell or klaxon or other equivalent warning system installed in addition to the craft's whistle or siren, for sounding the general emergency alarm signal, is to comply with the *International Life-saving Appliances (LSA) Code* and with the requirements of this Section, *see also* 1.15 and 1.16.

18.2.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 20.10 and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15.

18.2.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg. 3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.2.4 There are to be segregated cable routes to public rooms, alleyways, stairways, control stations and on passenger craft on open decks, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any public rooms, alleyways, stairways, control stations and on passenger craft on open decks, albeit at a reduced capacity.

18.2.5 Where the special alarm fitted to summon the crew, operated from the navigation bridge, or fire control station, forms part of the craft's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

18.2.6 The sound pressure levels are to be measured during a practical test and documented, *see* 21.2.

18.3 Public address system

18.3.1 Public address systems are to comply with the *International Life-saving Appliances (LSA) Code* and the requirements of this Section.

18.3.2 The public address system is to be provided with an emergency source of electrical power as required by 3.2, 3.3, 3.4 or 20.10 and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the public address system. Failure of any power supply is to operate an audible and visual alarm, *see also* 1.15 and 1.16.

18.3.3 The public address system is to have multiple amplifiers having their power supplies so arranged that a single fault will not cause the loss of the facility to broadcast emergency announcements in public rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

18.3.4 The public address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, as defined by SOLAS Reg. II-2/A, Reg.3.9, other than the zone in which the public address control station is located, will not interfere with the distribution in any other such zone.

18.3.5 There are to be segregated cable routes to public rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any public rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

18.3.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the public address system, for tone signals.

18.3.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

18.3.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

18.3.9 Where the public address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of 18.2:

(a) The emergency system is given automatic priority over any other system input.
(b) More than one device is provided for generating the sound signals for the emergency alarms.

18.3.10 Where more than one alarm is to be sounded through the public address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

18.3.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals, and documented, *see* 21.2.

18.4 Escape route or low location lighting (LLL)

18.4.1 Where required escape route or low location lighting (LLL) is satisfied by electric illumination, the LLL system is to comply with the requirements of this sub-Section.

18.4.2 The LLL system is to be provided with an emergency source of electrical power and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also* 1.16.

18.4.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with 11.5.3, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes, *see* 12.3.7.

18.4.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

■ *Section 19*
Craft safety systems

19.1 Watertight doors

19.1.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the waterline in the final condition of damage or above the bulkhead deck as applicable and for passenger craft be capable of being automatically supplied by the transitional source of emergency electrical power required by 3.2.9 or, where applicable, 3.3.9 in the event of failure of either the main or emergency source of electrical power.

19.1.2 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

19.1.3 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

19.1.4 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

19.1.5 The enclosures of electrical components necessarily situated below the waterline in the final condition of damage or below the bulkhead deck as applicable are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529 or an acceptable and relevant national standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 Standard.
(b) Door position indicators and associated circuit components protected to IPX8 Standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 Standard.

19.1.6 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the craft may sustain is minimised.

19.1.7 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in passenger areas and areas where the noise level exceeds 85 dB(A).

19.1.8 A central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) a 'local control' mode for normal use which is to allow any door to be locally opened and locally closed after use without automatic closure, and;

(b) a 'doors closed' mode for emergency use which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

19.1.9 The 'master mode' switch is to be arranged to be normally in the 'local control' mode position; be clearly marked as to its emergency function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

19.1.10 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

19.1.11 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

19.2 Shell doors, loading doors and other closing appliances

19.2.1 Where it is required that indicators be provided for shell doors, loading doors and other closing appliances, which are intended to ensure the watertight integrity of the craft's structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

19.2.2 Where such doors and appliances are to be operated at sea, the requirements of 19.1 are to be complied with as far as is practicable.

19.2.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

■ *Section 20*
Cargo craft, patrol and pilot craft, workboats and other similar craft of less than 500 tons gross tonnage for operation in Service Groups 1 to 3, and yachts less than 500 gt

20.1 General requirements

20.1.1 The requirements of this Section are applicable to electrical installations where the voltage of supply does not exceed 440 V a.c. or d.c.

20.1.2 The electrical installations for propulsion and auxiliary service where the voltage of supply exceeds 440 volts are to be constructed and installed in accordance with Sections 1 to 18.

20.1.3 Cargo craft of 300 tons gross tonnage and above are also to comply with 3.7.

20.1.4 Alternative arrangements, including those in accordance with IEC 60092-507:2008-01, *Electrical installations in ships – Small vessels*, or a relevant International or National Standard acceptable to LR may be considered.

20.2 Plans

20.2.1 At least three copies of the plans and particulars in 20.2.2 to 20.2.6 are to be submitted for consideration. Single copies only are required of plans in 20.2.7.

20.2.2 Single line diagram of main power and lighting systems which is to include:

(a) rating of machines; transformers; batteries and semi-conductor converters;

(b) all feeders connected to the main switchboard;

(c) section boards and distribution boards;

(d) insulation type, size and current loadings of cables;

(e) make, type and rating of circuit breakers and fuses.

20.2.3 Simplified diagrams of generator circuits and feeder circuits showing:

(a) protective devices;

(b) instrumentation and control devices;

(c) preference tripping;

(d) earth fault indication/protection.

20.2.4 Calculations of short circuit currents at main switchboard and distribution boards, details of circuit breaker and fuse operating times and discrimination curves.

20.2.5 For battery installation, arrangement plans and calculations are to show compliance with 20.12.

20.2.6 Details of electrically operated personnel safety systems which are to include single line diagrams and a general arrangement plan of the vessel showing location and cable routes of:

(a) fire detection, alarm and extinction systems;
(b) internal communication and alarm systems.

20.2.7 Schedule of normal operating loads on the system.

20.3 Survey

20.3.1 The installation is to be inspected and tested by the Surveyors, in accordance with the requirements of Section 21, as appropriate, and is to be to their satisfaction.

20.4 Addition or alterations

20.4.1 No addition, temporary or permanent is to be made to an approved installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment, including cables and switchgear, are adequate for the increased load.

20.4.2 Plans are to be submitted for consideration, and the alterations or additions are to be carried out under the survey and to the satisfaction of the Surveyors.

20.5 Location and construction of equipment

20.5.1 Electrical equipment is to be accessibly placed, clear of flammable material in well ventilated, adequately lighted spaces, in which flammable gases cannot accumulate and where it is not exposed to risk of mechanical damage or damage from water, steam or oil. Where necessarily exposed to such risks, the equipment is to be suitably constructed or enclosed. Equipment is to be accessible for maintenance.

20.5.2 Insulating materials and insulated windings are to be flame retardant, and resistant to tracking, moisture, sea air and oil vapour unless special precautions are taken to protect them.

20.5.3 Securing arrangements used in connection with current carrying parts are to be effectively locked.

20.5.4 The operation of all electrical equipment is to be satisfactory under such conditions of vibrations, movements and shock as may arise in normal practice.

20.5.5 The design and installation of electrical equipment is to be such that the risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions. Equipment is to be tested at the manufacturer's works and a certificate of tests issued by the manufacturer.

20.6 Systems of distribution

20.6.1 The following systems of generation and distribution are acceptable:

(a) two wire insulated;
(b) two wire with one pole earthed;
(c) three phase three wire insulated neutral;
(d) three phase, four wire with neutral earthed but without hull return.

20.6.2 A device(s) is to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits to continuously monitor the insulation level to earth.

20.7 Earthing

20.7.1 Except where exempted by 20.7.2 all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed.

20.7.2 The following parts may be exempted from the requirements of 20.7.1:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported in lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a voltage not exceeding 55V direct current or 55V root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(j) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

20.7.3 With wood and other non-metallic hull constructions earthing connections are to be made to the generator frame, engine bedplate and earthing plate. Earthing connections are not to be made to hull sheathing, skin fittings or plumbing.

20.8 Protection

20.8.1 Installations are to be protected against over-currents including short circuits. The tripping/fault clearance times of protective devices are to provide complete and co-ordinated protection to ensure:
(a) availability of services not affected by the faulty circuit;
(b) elimination of the fault to reduce damage to the system and hazard of fire.

20.8.2 Short circuit protection and a means of complete isolation is to be provided for each source of power.

20.8.3 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments; batteries used solely for engine starting may be provided with only a means of isolation.

20.8.4 Short circuit and overload protection together with a means of isolation is to be provided in each non-earthed outgoing circuit of the main switchboard and each distribution board.

20.8.5 Each final sub-circuit is to be provided with short circuit protection and a means of isolation in each non-earthed line.

20.8.6 Lighting circuits are to be supplied by circuits separate from those for power.

20.8.7 Control circuits for engine monitoring and other services are to be provided with short circuit protection.

20.8.8 Protective devices are not to be fitted in any earthed line of a distribution system.

20.8.9 Circuit breakers and fuses are to have a certified fault rating adequate for the installation and are to comply with a National or International Standard.

20.8.10 In the absence of precise data the calculation methods given in 6.2.4 are to be used for evaluation of short circuit currents.

20.8.11 Generators for a.c. systems are to be provided, as a minimum, with the protective gear required by 6.8.2 and 6.8.3 and additionally provided with the instrumentation required by 7.11.

20.9 Quality of power supplies

20.9.1 Unless specified otherwise electrical equipment, other than that supplied by battery systems, is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:
(a) Voltage:
- Permanent variations +6 per cent, –10 per cent
- Transient recovery +20 per cent, –15 per cent
- Recovery time 1,5 seconds.

(b) Frequency:
- Permanent variations ±5 per cent
- Transient variations ±10 per cent
- Recovery time five seconds.

20.9.2 Generator voltage regulators and engine governors are to be such as to ensure that the above supply variations are not exceeded.

20.10 Sources of electrical power

20.10.1 Under sea-going conditions where electrical power is required for services for the propulsion, navigation and safety of the craft and crew, it is to be provided by either a generator(s) having a rating sufficient to ensure the operation of these services or by an engine-driven charging system in conjunction with a battery(ies).

20.10.2 Under emergency conditions where electrical power is required for lighting to enable persons to evacuate the craft, for navigational lights, fire detection and alarm systems and internal communication and alarm systems, it is to be provided by alternative source(s) of electrical power located separately from the source(s) of power in 20.10.1 and suitably located for use in an emergency. This source(s) of electrical power is to be adequate to permit evacuation and to supply the navigation lights, fire detection and alarm systems and internal communication and alarm systems, for a period of 5 hours duration.

20.10.3 Where electrical power is required for services for the propulsion, navigation and safety of the yacht or craft and for the safety of the crew it is to be provided by:
(a) for **non-passenger type yachts of scantling length between 24 m and 50 m**, at least two generators having ratings sufficient to ensure the operation of these services when any one generator is out of action; or
(b) for **non-passenger type service craft for Service Groups 1 to 3**, a generator(s) having a rating sufficient to ensure the operation of these services without being overloaded.

20.10.4 Additionally, for **non-passenger type yachts of scantling length between 24 m and 50 m**:
(a) generators fitted to satisfy the requirements of 20.10.3(a) may be driven by the main engine provided the requirements of 20.9.1 are satisfied for all main engine speed and load conditions and that there is at least one of the remaining generators driven by a prime mover independent of the main engine; and
(b) any batteries provided for the duty, referred to in 20.10.2, are to be rated for at least 5 hours duration.

20.10.5 Additionally, for **non-passenger type service craft for Service Groups 1 to 3**, in a single generator installation, or where in a multiple generator installation with one generator out of action the remaining generator(s) is not capable of supplying the circuits serving any safety, essential lighting and communication equipment, an alternative source of electrical power of 5 hours duration is to be provided for these services.

20.11 Cables

20.11.1 Cables and cable installations are to be in accordance with the requirements of Section 11.

20.12 Batteries

20.12.1 Batteries and battery installations are to be in accordance with the requirements of Section 12.

20.13 Lightning conductors

20.13.1 Lightning conductors complying with IEC 60092-401 are to be fitted to each mast of all wood, composite and steel craft having wooden masts or topmasts. They need not be fitted to steel craft having steel masts.

20.14 Fire detection and alarm systems

20.14.1 Where a fire detection and alarm system is fitted, it is to be in accordance with the requirements of 17.1.

20.15 Internal communication and alarm systems

20.15.1 Where internal communication and alarm systems are provided for use in an emergency, they are to comply with the requirements of 18.2 and 18.3 as appropriate.

■ *Section 21* Testing and trials

21.1 Testing

21.1.1 Tests in accordance with 21.1.2 to 21.1.4 are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

21.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:

(a) all current carrying parts connected together and earth;

(b) all current carrying parts of opposite polarity or phase.

For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with Table 2.21.1. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for one minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 2.21.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \leq 60$	500
$60 < U_n \leq 1000$	$2 \times U_n + 1000$
$1000 < U_n \leq 2500$	6500
$2500 < U_n \leq 3500$	10000
$3500 < U_n \leq 7200$	20000
$7200 < U_n \leq 12000$	28000
$12000 < U_n \leq 15000$	38000

21.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

21.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth;

(b) all current carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in Table 2.21.2.

Table 2.21.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1
$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

21.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

21.2 Trials

21.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in 21.2.2 to 21.2.7 are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works.

21.2.2 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth; and, so far as is reasonably practicable,
(b) all current carrying parts of different polarity or phase;

The minimum values of test voltage and insulation resistance are given in Table 2.21.2. The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

21.2.3 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;
(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by 1.12.2 or 20.7.2;
(c) bonding for the control of static electricity.

21.2.4 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;
(b) temperature of joint, connections, circuit-breakers and fuses;
(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;
(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;
(e) voltage drop at the worst case condition;
(f) harmonic distortion of the voltage waveform, where declared;
(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;
(h) alarm sound pressure levels; and
(j) all essential and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory.

21.2.5 Measurements are to be taken as part of the trials specified in 21.2.4(c), (d), (e) and (f) to verify that the installation will provide a quality of power supply in accordance with the values listed in 1.8.

21.2.6 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew and passenger emergency and craft safety systems.

21.2.7 On completion of the general emergency alarm system and public address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

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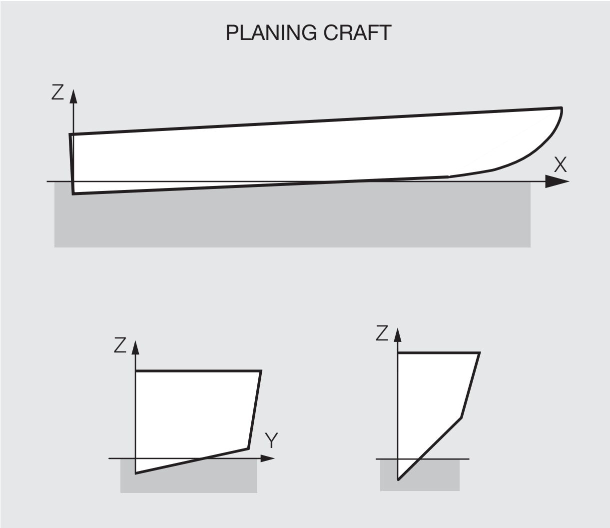
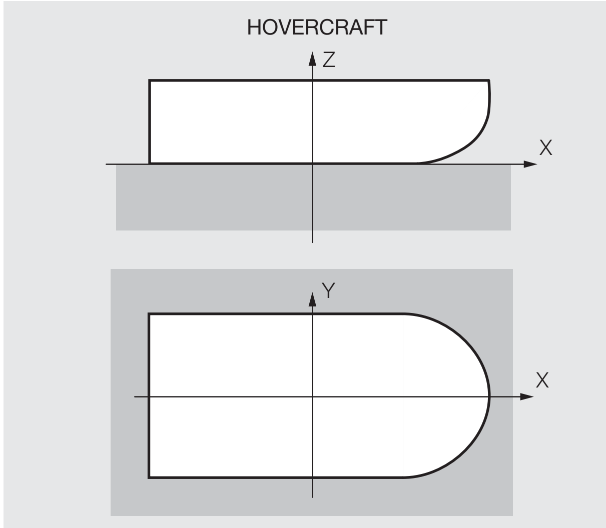
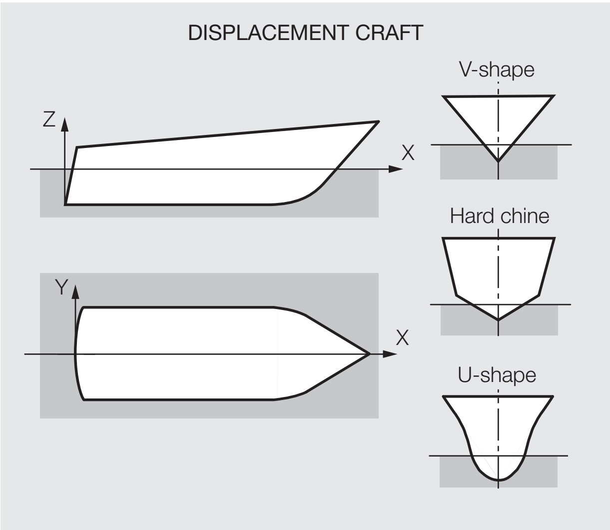
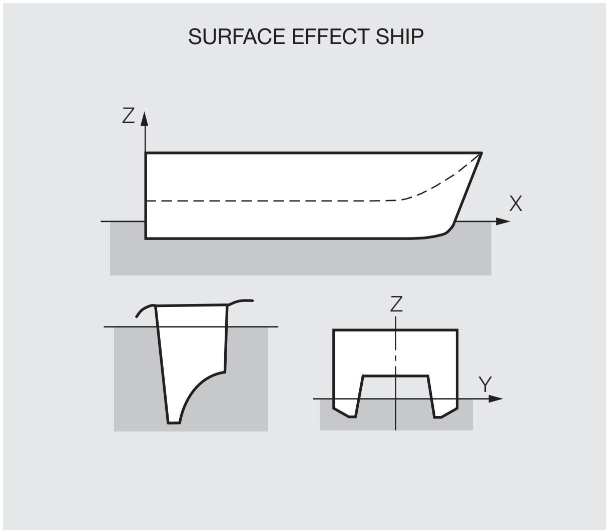
LIFE MATTERS

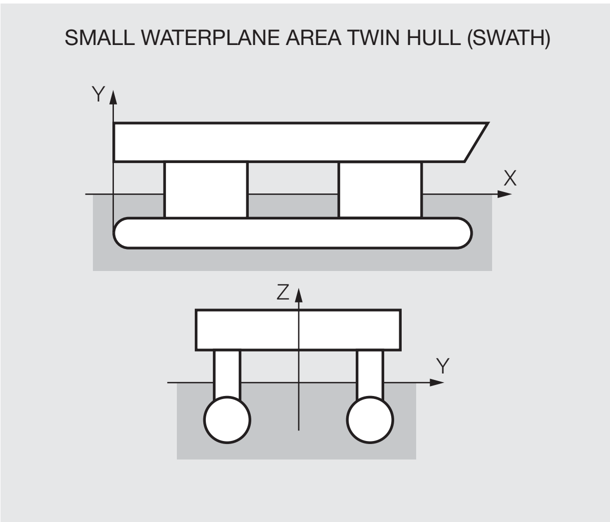
DIFFERENT TYPES OF HULL FORMS COVERED BY THE SPECIAL SERVICE CRAFT RULES

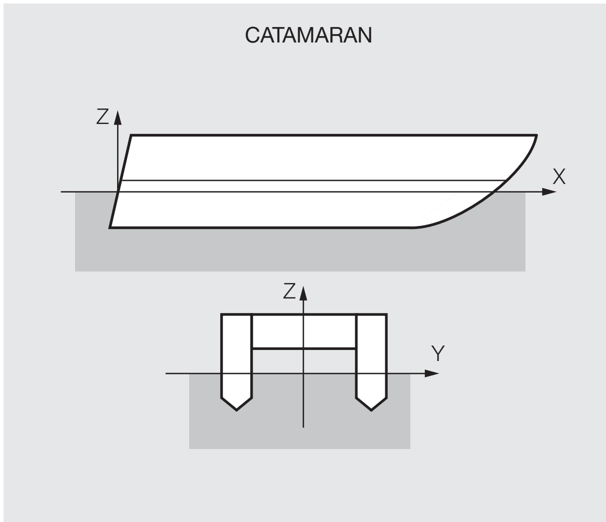




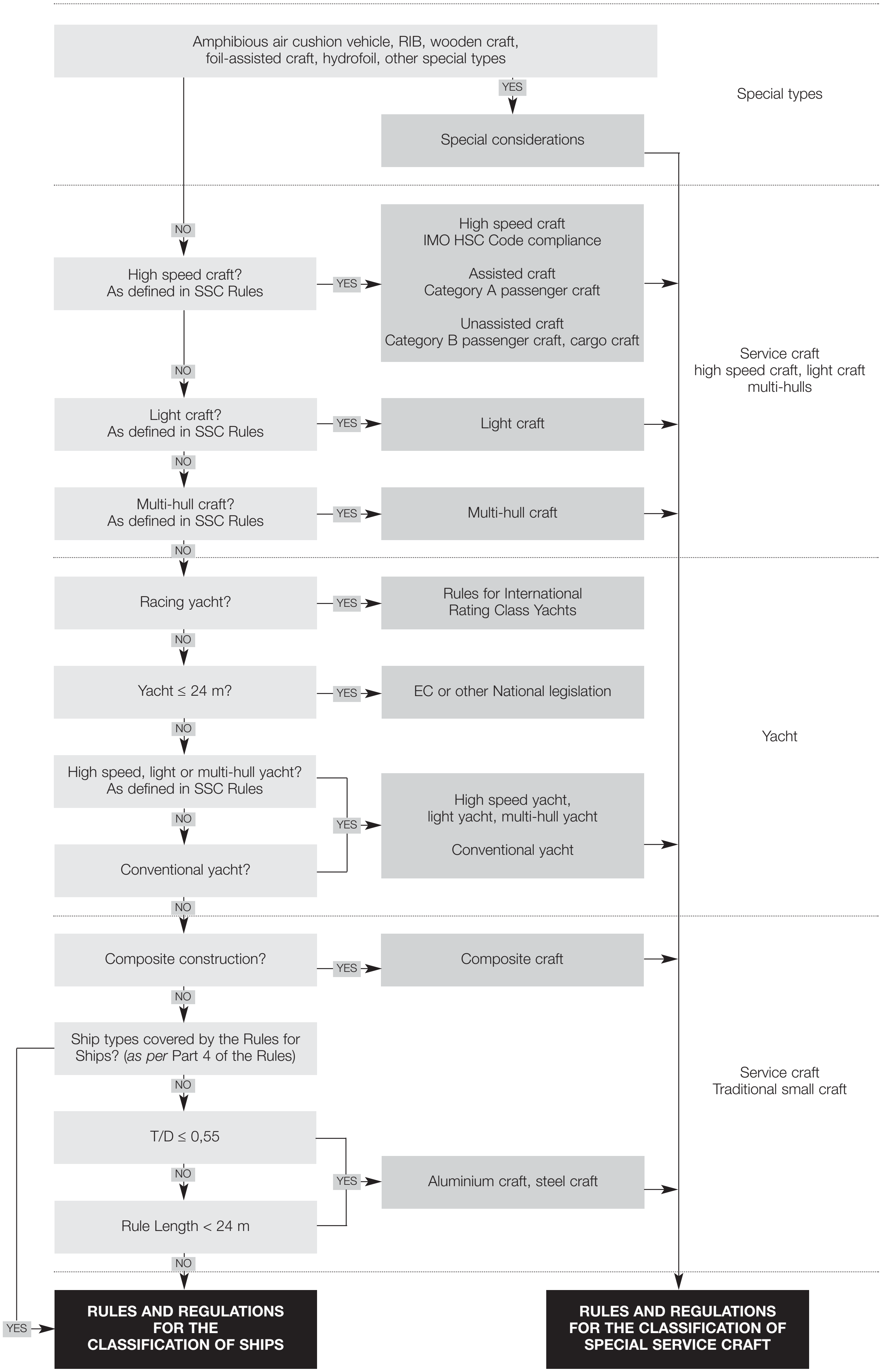








DIFFERENT TYPES OF CRAFT COVERED BY THE SPECIAL SERVICE CRAFT RULES



Chapter Contents

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Section 1
General requirements

1.1 Application

1.1.1 The requirements of this Part apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater, 3000 gross registered tonnage or less, and intended for the carriage of 12 passengers or less, and service craft (*see also* 1.1.2(c)) built in accordance with these Rules.

1.1.2 Consideration will be given to the acceptance of fire safety measures:

(a) which, for Service Craft, have been prescribed and approved by the Government of the Flag State. In this instance, the requirements of Chapter 2 and Chapter 4 of these Rules are not applicable;

(b) which, for yachts, have been prescribed and approved by the Government of the Flag State, provided these are shown to be equivalent to those required by the MCA LY2 Code as amended. In this instance, the requirements of Chapter 3 and Chapter 4 of these Rules are not applicable;

(c) where the arrangements are considered equivalent to those required by these Rules as a result of risk assessment studies; or

(d) where the arrangements are considered acceptable compared to those required by these Rules, due cognisance having been taken of any restricted service limits.

1.1.3 Special consideration, consistent with the fire hazard involved, will be given to construction or arrangements not covered by this Chapter.

1.1.4 High speed cargo craft of 500 gross tons and over on international voyages and high speed passenger craft on international voyages are to be provided with the fire safety measures required by the *International Convention for the Safety of Life at Sea, 1974* as amended (SOLAS 74), Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*).

1.1.5 High speed cargo craft of 500 gross tons and over employed on national voyages and high speed passenger craft employed on national voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.6 High speed cargo craft of less than 500 gross tons employed on national or international voyages are to comply with the fire safety measures of the Government of the Flag State.

1.1.7 It is the responsibility of the Government of the Flag State to give effect to the fire safety measures of 1.1.4, 1.1.5 and 1.1.6. However, Lloyd's Register (hereinafter referred to as LR) will undertake to do this in cases where:

(a) Contracting Governments have authorised LR to apply the requirements of SOLAS 74 and issue the appropriate certification on their behalf; or

(b) the Government of the Flag State is not a signatory to SOLAS 74; or

(c) the craft is to be classed for restricted or special service in national waters and the Government of the Flag State has no National requirements.

1.1.8 When implementing the provisions of 1.1.7, LR will apply the fire safety measures required by SOLAS 74 Chapter X – Safety Measures for High Speed Craft (*International Code of Safety for High Speed Craft*). However, due consideration will be given to arrangements deemed to provide an equivalent level of fire safety, taking due cognisance of the circumstances of the restricted or special service.

1.2 Submission of plans and information

1.2.1 The plans and information detailed in 1.2.2 to 1.2.4, where applicable, are to be submitted at least in triplicate for approval, together with all additional information such as gross tonnage and number of passengers/guests.

1.2.2 For fire protection, the following plans and information are to be submitted:

(a) Structural fire protection plan showing extent of materials used in construction, steel, aluminium, or alternative forms of construction, together with details of the thermal characteristics of the alternative forms of construction that include the temperature at which the material starts to lose its strength, and proposals for protection, etc.

(b) A general arrangement plan showing the main fire zones, escape stairways and the fire compartmentation bulkheads and decks within the main fire zones, including engine rooms, galleys, bonded stores, paint stores, navigating bridge, radio room, fire-fighting control room, emergency generator rooms and battery locker, helicopter arrangements, including re-fuelling and petrol stowage arrangements.

(c) A plan showing the details of construction of the fire protection bulkheads and decks and particulars of any surface laminates employed.

(d) Copies of Certificates of Approval by National Authorities and Fire Test Reports in respect of all 'A' and 'B' Class fire divisions, non-combustible materials and materials having low flame-spread characteristics, etc., which are to be used but have not been approved by LR. Copies of Certificates issued by other recognised approval bodies may be submitted for consideration.

(e) A ventilation plan showing ducts and any dampers in them, closing appliances and the position of the controls for stopping the system.

(f) A plan showing the fire detection and alarm system.

(g) A plan showing the remote control system for fire doors, if applicable.

(h) A fire control plan meeting the requirements of Ch 4,5.

1.2.3 For fire-extinguishing the following plans are to be submitted:

(a) A general arrangement plan showing the disposition of all the fire-fighting equipment including the fire main, the fixed fire-extinguishing systems; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the firemen's outfits.

(b) A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials, and the cross connections to any other system.

(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.

1.2.4 Fire-control plans as required by Ch 4,5 are to be submitted.

1.2.5 For yachts, where fire plans and the information listed above have been appraised, approved and verified on board by the Flag Administration in compliance with the MCA LY2 Code as amended, Lloyd's Register will only acknowledge the aforementioned and therefore no further appraisal, approval or survey should be provided.

■ *Section 2* **Definitions**

2.1 Materials

2.1.1 **Non-combustible material** means a material which neither burns nor gives off flammable vapours in sufficient quantity for self-ignition when heated to approximately 750°C, according to an established test procedure, *see* IMO *International Code for Application of Fire Test Procedures* (FTP Code), Annex 1, Part 1. Any other material is a **combustible material**.

2.1.2 **Steel or other equivalent material**. Where the words 'steel or other equivalent material' occur, 'equivalent material' means any non-combustible material which, by itself, or due to insulation provided, has structural and integrity properties equivalent to steel at the end of the applicable fire exposure to the standard fire test (e.g. aluminium with appropriate insulation).

2.1.3 **Alternative forms of construction** means any combustible material may be accepted if it can be demonstrated that the material, which by itself or due to insulation provided has structural and fire integrity properties equivalent to 'A' or 'B' class divisions, or steel, as applicable, at the end of the applicable fire exposure to the standard fire test.

2.2 Fire test

2.2.1 A **standard fire test** is one in which the specimens of the relevant bulkheads and decks are exposed in a test furnace to temperatures corresponding approximately to the standard time-temperature curve. The test methods are to be in accordance with the IMO FTP Code, Annex 1, Part 3.

2.3 Flame spread

2.3.1 **Low flame spread** means that the surface thus described will adequately restrict the spread of flame, having regard to the risk of fire in the spaces concerned, this being determined by an acceptable test procedure, *see* IMO FTP Code, Annex 1, Part 5.

2.3.2 **Not readily ignitable** means that the surface thus described will not continue to burn for more than 20 seconds after the removal of a suitable impinging test flame.

2.4 Ship divisions and spaces

2.4.1 **'A' Class divisions** are those divisions formed by bulkheads and decks, and:

(a) Are to be constructed of steel or other equivalent material.

(b) Are to be suitably stiffened.

(c) Are to be so constructed as to be capable of preventing the passage of smoke and flame up to the end of the one-hour standard fire test, *see* 2.2.1.

(d) Are to be insulated with approved non-combustible materials such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature, at any one point, including any joint, rise more than 180°C above the original temperature, within the time listed below:

Class 'A-60'	60 minutes.
Class 'A-30'	30 minutes.
Class 'A-15'	15 minutes.
Class 'A-0'	0 minutes.

(e) May be required to demonstrate that they meet the above requirements for integrity and temperature rise, through a test.

2.4.2 **'B' Class divisions** are those divisions formed by bulkheads, decks, ceilings or linings and:

(a) Are to be so constructed as to be capable of preventing the passage of flame to the end of the first half hour of the standard fire test, *see* IMO FTP Code, Annex 1, Part 3.

(b) Are to be insulated such that the average temperature of the unexposed side will not rise more than 140°C above the original temperature, nor will the temperature at any one point, including any joint, rise more than 225°C above the original temperature, within the time listed below:

Class 'B-15'	15 minutes.
Class 'B-0'	0 minutes.

(c) Are to be constructed of approved non-combustible materials and all materials entering into the construction and erection of 'B' Class divisions are to be non-combustible, except where permitted by other requirements of this Chapter.

(d) May be required to ensure that they meet the above requirements for integrity and temperature rise through a test of a prototype division.

2.4.3 **'C' Class divisions** are divisions to be constructed of approved non-combustible materials. They need to meet neither requirements relative to the passage of smoke and flame nor limitations relative to the temperature rise. Combustible veneers are permitted provided they meet other requirements of this Chapter.

2.4.4 **Continuous 'B' Class ceilings or linings** are those 'B' Class ceilings or linings which terminate only at an 'A' or 'B' Class division.

2.4.5 **Accommodation spaces** are those spaces used for public spaces, corridors, lavatories, cabins, offices, hospitals, cinemas, games and hobbies rooms, pantries containing no cooking appliances and similar spaces.

2.4.6 **Service spaces** are those used for galleys, pantries containing cooking appliances, stores, mail and specie rooms, store rooms, lockers, workshops other than those forming part of the machinery spaces and similar spaces and trunks to such spaces.

2.4.7 **Cargo spaces** are all spaces used for cargo (including cargo oil tanks) and trunks to such spaces.

2.4.8 **Machinery spaces of Category A** are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or oil fuel unit.

2.4.9 **Machinery spaces** are all machinery spaces of Category 'A' and all other spaces containing propelling machinery, boilers, oil fuel units, steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air conditioning machinery, and similar spaces; and trunks to such spaces.

2.4.10 **Control stations** are those spaces in which the craft's radio or main navigating equipment or the emergency source of power is located or where the fire recording or fire-control equipment is centralised.

2.4.11 **Cargo area** is that part of the craft that contains cargo tanks, slop tanks and cargo pump rooms including pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the entire length and breadth of the part of the craft over the above-mentioned spaces.

2.4.12 **Main vertical zones** are those sections into which the hull, superstructure and deck houses are divided by 'A' Class divisions, the mean length and width of which on any one deck does not, in general, exceed 48 m.

2.5 Equipment

2.5.1 **Oil fuel unit** is the equipment used for the preparation of oil fuel for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes any oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 1,8 bar (1,8 kgf/cm^2) gauge.

2.6 Craft types

2.6.1 For the purpose of this Part the definitions of craft types given in 2.6.2 and 2.6.3 apply.

2.6.2 A **passenger craft** is a craft which carries more than twelve passengers.

2.6.3 A **yacht** is a recreational craft used for sport or pleasure and may be propelled mechanically, by sail or by a combination of both.

Section

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to service craft built in accordance with these Rules.

1.1.2 Where service craft incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

Section 2 Fire safety measures for service craft

2.1 General

2.1.1 Table 2.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2, are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200ºC above the ambient temperature at any time during the specified fire exposure.

Table 2.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted, subject to requirements in high fire risk areas
Passive fire protection, *see* 2.3 to 2.6	Category 'A' machinery spaces: • For craft >150 gross tons: A-30/A-0 • For craft <150 gross tons: A-0 Galleys: • For craft >50 gross tons: B-15
Means of escape, *see* 2.7: • Machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 2.13	• Fitted in all machinery spaces • Fitted in stairways, service spaces, machinery spaces, control stations and accommodation spaces of craft >50 gross tons with sleeping accommodation
Fire pumps, *see* 2.14	• 1 fixed power pump + 1 portable pump • For craft <150 gross tons: 1 portable pump
Fire-extinguishing arrangements in machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2, but need not exceed 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	Sufficient to ensure that at least one will be readily available in every compartment

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' class divisions.

2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category 'A' machinery spaces are to be enclosed by A-30 Class divisions where adjacent to accommodation spaces, or control positions and A-0 Class divisions elsewhere. For craft below 150 gross tons, Category 'A' machinery spaces are to be enclosed by A-0 Class divisions, regardless of adjacent space use.

2.4.2 For craft greater than 50 gross tons, galleys are to be enclosed by B-15 Class divisions unless the cooking appliances contained therein have an insignificant fire risk.

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,17.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., are to be regarded as having a significant fire risk.

2.4.3 Openings in 'A' Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.4 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel or other equivalent material.

2.4.5 Doors are to be self-closing in way of Category 'A' machinery spaces.

2.4.6 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.7 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Paints, varnishes and other finishes used on exposed interior surfaces are not to be capable of producing excessive quantities of smoke, toxic gases or vapours and are to be of the low flame spread type. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 5.

2.5.2 Except in refrigerated compartments of service space, all insulation (e.g. fire and comfort) is to be of non-combustible materials.

2.5.3 Pipes penetrating 'A' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges, and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving crew spaces and other spaces to which the crew normally have access are to be arranged so as to provide ready means of escape to a deck from which disembarkation may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of crew and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation spaces, service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck is to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) The second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(c) No dead-end corridors having a length of more than 7 m will be accepted. A ‘dead-end corridor’ is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impractical. Escape is to be by steel ladders that are as widely separated as possible.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see also* Pt 16, Ch 2,17.6.

2.8.2 Ventilation ducts for Category ‘A’ machinery spaces and exhaust ducts for galleys of significant fire risk are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category ‘A’ machinery spaces unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build-up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arrestors.

2.8.5 Ventilation systems serving Category ‘A’ machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas that may be emitted from batteries. The requirements of Pt 16, Ch 2,12.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. Ventilation grills are to be of non-combustible material. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In service craft in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the service craft and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category ‘A’ machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in machinery spaces and, where necessary, other spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the craft are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 In Category 'A' machinery spaces means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, in a position where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the service craft and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system is to be installed in all Category 'A' machinery spaces and is to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 In craft over 50 gross tons, where sleeping accommodation is provided on board, a fixed fire detection and fire-alarm system is to be installed in all stairways, service spaces, machinery spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

2.14 Fire pumps and fire main system

2.14.1 **Application**:

(a) Every service craft is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Chapter.
(b) For very small service craft, where it is not considered possible to fit a fire pump, the arrangements will be specially considered.

2.14.2 **Capacity of fire pumps**. The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour

where
B = greatest moulded breadth of craft, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of craft, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hours.

2.14.3 **Fire pumps**:

(a) In service craft of 150 tons gross or more, a minimum of one fixed power pump and one portable pump, complying with 2.14.4, are to be provided.
(b) For service craft of less than 150 tons gross, one portable pump or alternative as required by 2.14.4, is to be provided.
(c) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.
(d) In service craft classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.
(e) Relief valves are to be provided in conjunction with any fire pumps if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.
(f) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:

(i) The pump is to be self priming.

(ii) The suction head in operation is not to exceed 4,5 m.

(iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m, or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater. The jet throw required need not exceed the length of the craft.

(iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.

(v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60ºC, further consideration will be given to the fire safety aspects.

(vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category 'A' machinery space.

(vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.

(viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).

(ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the craft's motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.

(x) Any diesel-driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0ºC by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:

(i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category 'A' machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category 'A' machinery space. In the case of craft defined in 2.14.3(b), the pump may be situated in the Category 'A' machinery space, if so desired.

(ii) The sea valve is to be capable of being operated from a position near the pump.

(iii) The space where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power, except for craft defined in 2.14.3(b), and is to be well ventilated.

(iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.

(v) The pump may also be used for other suitable purposes, subject to approval in each case.

(vi) The pressure and quantity of water delivered by the pump is to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(vii) In the case of craft defined in 2.14.3(b), a fire main, hydrants and hoses are to be installed in accordance with 2.14.5 to 2.14.10.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a).

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged by cargo.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to the crew while the service craft is being navigated and any part of any cargo space when empty. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangements of pipes and hydrants is to be such as to avoid the possibility of freezing. In service craft where deck cargo may be carried, the positions of the hydrants are to be such that they are always readily accessible and the pipes are to be arranged, as far as practicable, to avoid risk of damage by such cargo. Unless one hose and nozzle is provided for each hydrant in the service craft, there is to be complete interchange-ability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pumps are at work.

(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
- (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the service craft, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
- (ii) The fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) The number of fire-hoses to be provided, each complete with couplings and nozzles, is to be one for each 15 m length of the service craft, or part thereof, but need not exceed the number of hydrants provided. This number does not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient numbers are available and accessible at all times.

2.14.10 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump(s).

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in Category 'A' machinery spaces

2.15.1 Except where provided for in 2.15.2, Category 'A' machinery spaces are to be provided with:

(a) one of the fixed fire-extinguishing systems given in Ch 4,3; and

(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 Where the size of the machinery space precludes access under normal operating conditions, provision is to be made such that a manually-released extinguishing medium, of a type allowed in Chapter 4, can be remotely discharged into the space. Such arrangements may utilise a portable extinguisher of adequate size. Details of the arrangements with supporting calculations are to be submitted for approval.

2.16 Fire-extinguishing appliances in other machinery spaces

2.16.1 Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15 and 2.17, there is to be provided in, or adjacent to, that space a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.17 Machinery spaces in craft which are constructed mainly or wholly of alternative forms of construction

2.17.1 Machinery spaces in craft which are constructed mainly or wholly with alternative forms of construction that contain internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.18 Fixed fire-extinguishing systems not required by this Chapter

2.18.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.19 Portable fire-extinguishers

2.19.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.19.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.19.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.19.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the craft.

2.19.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment.

2.19.6 Where cooking facilities are provided a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.20 Fire blanket

2.20.1 A fire blanket is to be installed in all galleys.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area 4 m^2 or over are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Arrangements where deep-fat cooking equipment is installed

2.22.1 Where deep-fat cooking equipment is installed in high speed craft, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) means to automatically shut off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

2.23 Helicopter decks

2.23.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.23.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 2.24.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.24 Fireman's outfit

2.24.1 All service craft of 350 gross tons or more and having enclosed spaces which are normally accessible, are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.25 Fire-control plans

2.25.1 Fire-control plans are to meet the requirements of Ch 4,5.

Section 1 General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to yachts with an overall length, L_{OA} (as defined in Pt 3, Ch 1,6.2.4) of 24 m or greater built in accordance with the Rules.

1.1.2 Where yachts incorporate fire hazards not covered in this Part, appropriate fire protection, detection and extinction arrangements are to be provided. Details are to be submitted for approval.

1.1.3 For yachts with an overall length of 24 m or more, and less than 500 gt, the fire safety measures are to comply with Section 2.

1.1.4 For yachts 500 gt or more, the fire safety measures are to comply with Section 3.

Section 2 Fire safety measures for yachts of overall length greater than 24 m but less than 500 gt

2.1 General

2.1.1 Table 3.2.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

Table 3.2.1 General fire protection, detection and extinction requirements

Form of construction, *see* 2.2	Steel or equivalent, or alternative forms of construction may be accepted subject to requirements
Passive fire protection, *see* 2.3 to 2.6	• Category 'A' machinery spaces 'A-30'/'A-0' • Galleys: 'B-15' where significant fire risk • Bulkheads in escape route corridors greater than 7 m in length: 'B-0' • Stairway enclosures: 'B-0'
Means of escape, *see* 2.7 • Category 'A' machinery spaces • Accommodation, etc.	2
Fixed fire detection system, *see* 2.13	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 2.14	1 fixed power pump + 1 portable pump
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 2.15	• A fixed fire-extinguishing system • A minimum of 2 and maximum of 5 portable foam extinguishers or equivalent
Portable fire-extinguishers in accommodation, *see* 2.18	At least 3
Automatic sprinkler system or equivalent, *see* 2.16	Fitted in yachts >350 gross tons

2.2 Forms of construction – Structure

2.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2, or be of alternative forms of construction, *see* Ch 1,2.1.3.

2.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk, *see* 2.4.2, and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 30 minutes exposure to the standard fire test.

2.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 2.2.2 are to be submitted.

2.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

2.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

2.3 Forms of construction – Fire divisions

2.3.1 Fire divisions required by 2.4 are to be constructed in accordance with the remaining paragraphs of this sub-Section.

2.3.2 Fire divisions using steel equivalent, or alternative forms of construction may be accepted if it can be demonstrated that the material by itself, or due to insulation provided, has the fire resistance properties equivalent to ‘A’ or ‘B’ Class divisions.

2.3.3 Insulation required by 2.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For ‘A’ Class divisions, the applicable exposure is 60 minutes, and for ‘B’ Class divisions, the applicable exposure is 30 minutes.

2.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

2.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

2.4 Structural fire protection

2.4.1 Category ‘A’ machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be enclosed by ‘A-30’ Class divisions where adjacent to accommodation or service spaces, control positions or each other, and ‘A-0’ Class divisions elsewhere.

2.4.2 Galleys are to be enclosed by ‘B-15’ Class divisions, unless the cooking appliances contained therein have an insignificant fire risk:

(a) For the purposes of this Chapter, coffee automats, toasters, dishwashers, microwave ovens, water boilers and similar appliances each with a maximum power of 5 kW may be regarded as having an insignificant fire risk. Electrically-heated cooking plates and hot plates for keeping food warm, each of them having a maximum power of 2 kW and a surface temperature not above 150°C may also be regarded as having insignificant fire risk. If spaces containing this equipment are lockable, then means of cutting-off the power to the space are to comply with Pt 16, Ch 2,17.6.7.

(b) Other equipment such as fat fryers, open flame cookers, etc., would be regarded as having a significant fire risk.

2.4.3 Where forming escape routes, corridor bulkheads and ceilings may be constructed of combustible materials provided they have a non-combustible core such that the ‘B-0’ Class standard fire test criteria are met.

2.4.4 Stairways connecting spaces below the main deck to the deck above are to be protected at one level by at least ‘B-0’ Class divisions and self-closing doors.

2.4.5 Lift and dumbwaiter trunks are to be enclosed by at least ‘B-0’ Class divisions and self-closing doors.

2.4.6 Openings in ‘A’ and ‘B’ Class divisions are to be provided with permanently attached means of closing that are to be at least as effective for resisting fires as the divisions in which they are fitted.

2.4.7 Interior stairways serving machinery spaces, accommodation spaces, service spaces or control stations are to be of steel, or other equivalent material.

2.4.8 Where ‘A’ Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.9 Where ‘B’ Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

2.4.10 Where the structure or ‘A’ Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

2.5 Materials

2.5.1 Except in refrigerated compartments of service spaces, all insulation other than fire insulation is to be of not-readily ignitable type. Fire insulation is to be of the non-combustible type.

2.5.2 Pipes penetrating ‘A’ or ‘B’ Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

2.5.3 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

2.5.4 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

2.5.5 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type that will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

2.5.6 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they are to be kept to the minimum quantity practicable and their exposed surfaces are to have low flame spread characteristics.

2.5.7 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

2.6 Surface of insulation

2.6.1 In spaces where penetration of oil products is possible, the surface of the insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages.

2.7 Means of escape

2.7.1 Stairways, ladders and corridors serving all spaces normally accessible are to be arranged so as to provide ready means of escape to a deck from which embarkation into survival craft may be effected.

2.7.2 Where reasonable and practicable, and having regard to the number of personnel involved and size of space, at least two means of escape, as widely separated as possible, are to be provided from each section of accommodation and service spaces and control stations:

(a) The normal means of access to the accommodation and service spaces below the open deck are to be arranged so that it is possible to reach the open deck without passing through intervening spaces containing a possible source of fire.

(b) Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route.

(c) This second means of escape may be through portholes, or hatches of adequate size, leading to the open deck.

(d) No dead-end corridors having a length of more than 7 m will be accepted. A 'dead-end corridor' is a corridor or part of a corridor from which there is only one escape route.

2.7.3 At least one of the means of escape from each space referred to in 2.7.2 is to be enclosed by 'B-0' Class divisions, unless it gives access directly to the open decks from the space.

2.7.4 At least two means of escape are to be provided from machinery spaces, except where the small size of the machinery space makes it impracticable. Escape is to be by steel ladders that are as widely separated as possible.

2.7.5 Lifts are not considered as forming a means of escape.

2.8 Ventilation systems

2.8.1 Ventilation fans are to be capable of being stopped, and main inlets and outlets of ventilation systems closed, from outside the spaces being served, *see* Pt 16, Ch 2,17.6.

2.8.2 Ventilation ducts for Category 'A' machinery spaces, exhaust ducts for galleys of significant fire risk, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.3 Ventilation ducts for accommodation spaces, service spaces or control stations are not to pass through Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, unless the ducts are constructed of steel and arranged to preserve the integrity of the division.

2.8.4 Store-rooms containing highly flammable products are to be provided with ventilation arrangements that are separate from other ventilation systems. Ventilation is to be arranged to prevent the build up of flammable vapours at high and low levels. The inlets and outlets of ventilators are to be positioned so that they do not draw from or vent into an area which would cause undue hazard, and are to be fitted with spark arresters.

2.8.5 Ventilation systems serving Category 'A' machinery spaces are to be independent of systems serving other spaces.

2.8.6 All enclosed spaces containing free-standing fuel tanks are to be ventilated independently of systems serving other spaces.

2.8.7 Ventilation is to be provided to prevent the accumulation of dangerous concentrations of flammable gas which may be emitted from batteries. The requirements of Pt 16, Ch 2,12.5 are to be complied with.

2.8.8 Ventilation openings may be fitted in and under the lower parts of cabin and public space doors in corridor bulkheads. The total net area of any such openings is not to exceed 0,05 m^2. Bridging ducts are not allowed in fire divisions.

2.8.9 For spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, *see* 2.20.1(d). For additional requirements for the ventilation of domestic gaseous fuel, *see* 2.11.

2.9 Fuel arrangements

2.9.1 In yachts in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

2.9.2 Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C.

2.9.3 Oil fuel, lubricating oil and other flammable oils are not to be carried in fore peak tanks.

2.10 Special arrangements in Category 'A' machinery spaces and, where necessary, other machinery spaces

2.10.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

2.10.2 The type of equipment installed and the layout of the yacht are to take account of the risk and spread of fire. Special attention is to be paid to the surroundings of open flame devices, hot areas and main and auxiliary machinery, oil and fuel overflows, and uncovered oil and fuel pipes.

2.10.3 Fuel filling, storage, venting and supply systems are to be installed so as to minimise the risk of fire and explosion.

2.10.4 Machinery components and accessories that require frequent maintenance and inspection are to be readily accessible.

2.10.5 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

2.10.6 Means of control are to be provided for:
(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) stopping ventilating fans; and
(d) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

2.10.7 The controls required in 2.10.6 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck. *See also* Pt 15, Ch 3,4.5.1 and 4.9.2.

2.11 Arrangements for gaseous fuel for domestic purposes

2.11.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel are to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons onboard is preserved. The installation is to be in accordance with recognised National or International Standards.

2.11.2 Storage lockers for gas cylinders are to be provided with:
(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining spaces.

2.11.3 Arrangements for storage on open deck will be specially considered.

2.12 Space heaters

2.12.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

2.13 Fixed fire detection and fire-alarm systems

2.13.1 A fixed fire detection and fire-alarm system are to be installed in all Category 'A' machinery spaces and are to comply with the requirements of Pt 16, Ch 1,2.8.

2.13.2 A fixed fire detection and fire-alarm system are to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system are to be installed in accordance with Ch 4,2.

2.13.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

2.13.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

2.14 Fire pumps and fire main system

2.14.1 **Application**. Every yacht is to be provided with a fire pump(s), fire mains, hydrants and hoses as required by this Section.

2.14.2 **Capacity of fire pumps**. The capacity of the fixed main fire pump(s) is not to be less than:

$$Q = (0{,}15\,(L_R\,(B + D))^{1/2} + 2{,}25)^2$$

but need not exceed 25 m^3/hour.

where
B = greatest moulded breadth of yacht, in metres
D = moulded depth to bulkhead deck, in metres
L_R = Rule length of yacht, as defined in Pt 3, Ch 1,6.2.1, in metres
Q = total capacity in m^3/hour.

2.14.3 **Fire pumps**:
(a) A minimum of one fixed power pump and one portable pump or alternative, complying with 2.14.4, are to be provided.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with ice clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(e) Where centrifugal pumps are provided in order to comply with this Section, a non-return valve is to be fitted in the pipe connecting each pump to the fire main.

2.14.4 **Portable fire pumps**:

(a) Except for electric pumps, which will be specially considered, portable fire pumps are to comply with the following:

- (i) The pump is to be self priming.
- (ii) The suction head in operation is not to exceed 4,5 m.
- (iii) The portable fire pump is to be fitted with a length of discharge hose and nozzle capable of maintaining a pressure sufficient to produce a jet throw of at least 12 m or that required to enable a jet of water to be directed on any part of the engine room or the exterior boundary of the engine room and casing, whichever is the greater.
- (iv) The pump set is to have its own fuel tank of sufficient capacity to operate the pump for three hours.
- (v) Details of the fuel type and storage location are to be submitted. If the fuel type has a flashpoint below 60ºC, further consideration will be given to the fire safety aspects.
- (vi) The pump set is to be stored in a secure, safe and enclosed space, accessible from open deck and clear of the Category ‘A’ machinery space.
- (vii) The pump set is to be easily moved and operated by two persons and be readily available for immediate use.
- (viii) Arrangements are to be provided to secure the pump at its anticipated operating position(s).
- (ix) The overboard suction hose is to be non-collapsible and of sufficient length to cater for the yacht’s motion under all operational conditions. A suitable strainer is to be fitted at the inlet end of the hose.
- (x) Any diesel driven power source for the pump is to be capable of being readily started in its cold condition down to a temperature of 0ºC by hand (manual) cranking.

(b) If it is not possible to comply with the requirements of 2.14.4(a), an additional fixed fire pump will be required, which is to comply with the following:

- (i) The pump, its source of power and sea connection are to be located in accessible positions outside the Category ‘A’ machinery space, or in a different space to the main fire pump, if the main fire pump is located outside the Category ‘A’ machinery space.
- (ii) The sea valve is to be capable of being operated from a position near the pump.
- (iii) The room where the fire pump prime mover is located is to be illuminated from the emergency source of electrical power and is to be well ventilated.
- (iv) If the pump is required to supply water for a fixed fire-extinguishing system in the space where the main fire pumps are situated, it is to be capable of simultaneously supplying water to this system and the fire main at the required rates.
- (v) The pump may also be used for other suitable purposes, subject to approval in each case.
- (vi) The pressure and quantity of water delivered by the pump are to be sufficient to produce a jet of water at any nozzle of not less than 12 m.

(c) Means to illuminate the stowage area of the portable pump and its necessary areas of operation are to be provided from the emergency source of electrical power.

(d) If preferred, a pump complying with 2.14.4(b) may be fitted instead of a portable pump complying with 2.14.4(a), *see also* 2.14.8(c).

2.14.5 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of the fixed main fire pump(s). The diameter of the water service pipes is to be sufficient to ensure an adequate supply of water for the operation of at least one fire-hose.

(b) The wash deck line may be used as a fire main provided that the requirements of this Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

2.14.6 **Pressure in the fire main**. When the fixed main fire pump, or the fire pump described in 2.14.4(b), is delivering the quantity of water required by 2.14.2 through the fire main, fire-hoses and nozzles, the pressure maintained at any hydrant is to be sufficient to produce a jet throw at any nozzle of not less than 12 m.

2.14.7 **Number and position of hydrants**. The number and position of the hydrants are to be such that at least one jet of water is to reach any part normally accessible to any person while the yacht is being navigated. Furthermore, such hydrants are to be positioned near the accesses to the protected spaces. At least one hydrant is to be provided in each Category ‘A’ machinery space.

2.14.8 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. For the use of aluminium alloy *see* Pt 15, Ch 1,10.1.4. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Where an additional fixed fire pump is fitted in accordance with 2.14.4(b) or 2.14.4(d):
  (i) An isolating valve is to be fitted in the fire main so that all the hydrants in the yacht, except those in the Category 'A' machinery space containing the main fire pump, can be supplied with water by the additional fixed fire pump. The isolating valve is to be located in an easily accessible and tenable position outside the Category 'A' machinery space; and
  (ii) the fire main is not to re-enter the machinery space downstream of the isolating valve.

2.14.9 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) A minimum of three fire-hoses are to be provided, each complete with couplings and nozzles. These numbers do not include any hoses required in any engine room. If necessary, the number of hoses is to be increased so as to ensure that hoses in sufficient number are available and accessible at all times.

2.14.10 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pump or pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) The size of nozzles intended for use in conjunction with a portable fire pump need not exceed 12 mm.

(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

2.15 Fire-extinguishing arrangements in machinery spaces

2.15.1 **Category 'A' machinery spaces** are to be provided with:

(a) One of the fixed fire-extinguishing systems given in Ch 4,3; and

(b) at least two portable foam extinguishers or equivalent, *see* Ch 4,6.3.2. Where internal combustion machinery is installed, an additional portable extinguisher is to be provided for every 375 kW of power output, but the total number of such additional extinguishers need not exceed five.

2.15.2 **Fire-extinguishing appliances in other machinery spaces**. Where a fire hazard exists in any machinery space for which no specific provisions for fire-extinguishing appliances are prescribed in 2.15.1 or 2.15.3 there is to be provided in or adjacent to that space, a satisfactory number of approved portable fire-extinguishers or other approved means of fire-extinction.

2.15.3 **Machinery spaces, other than Category 'A', in yachts which are constructed mainly or wholly with alternative forms of construction**. In yachts that are constructed mainly or wholly with alternative forms of construction, machinery spaces, other than Category 'A', containing internal combustion machinery, are to comply with the fire-extinguishing requirements for Category 'A' machinery spaces, *see* 2.15.1.

2.16 Automatic sprinkler, fire detection and fire-alarm system

2.16.1 A fixed automatic sprinkler must be fitted in yachts over 350 gross tons, fire detection and fire-alarm system, or equivalent system (e.g. watermist), are to be fitted in all stairways, service spaces, control stations and accommodation spaces, except in general, in spaces which afford no fire risk such as void spaces.

2.16.2 The arrangements are to be in accordance with Ch 4,1, particular attention should be given to Ch 4,1.2.16 and 1.2.17.

2.17 Fixed fire-extinguishing systems not required by this Section

2.17.1 Where a fixed fire-extinguishing system not required by this Chapter is installed, the arrangement is to comply with the relevant requirements of this Chapter.

2.18 Portable fire-extinguishers

2.18.1 All portable fire-extinguishers are to comply with the requirements of Ch 4,6.

2.18.2 The portable fire-extinguishers are to be stowed in readily accessible positions.

2.18.3 One of the portable fire-extinguishers intended for use in any space is to be stowed near the entrance to that space.

2.18.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

2.18.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than three.

2.18.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

2.19 Fire blanket

2.19.1 A fire blanket is to be installed in all galleys.

2.20 Protection of spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels

2.20.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.
(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo spaces, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connection for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.
(c) At least two portable foam extinguishers or equivalent.
(d) An independent mechanical ventilation system, which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 2.8.2, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.
(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,14.
(f) Prominently displayed 'No Smoking' signs.
(g) 'A-30' Class divisions where adjacent to Category 'A' machinery spaces, accommodation or service spaces, or control positions and 'A-0' Class divisions elsewhere.

2.20.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;
(b) no door hold back devices are fitted;
(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and
(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

2.20.3 The requirements of 2.9 are to be complied with, as appropriate.

2.21 Protection of paint lockers and flammable liquid lockers

2.21.1 Paint lockers and flammable liquid lockers with a deck area of 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

2.21.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

2.21.3 Lockers having a deck area of less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

2.22 Helicopter decks

2.22.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

2.22.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as in 2.23.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

2.23 Fireman's outfit

2.23.1 All yachts of 350 gross tons or more are to carry at least two fireman's outfits complying with the requirements of Ch 4,4.

2.24 Fire-control plans

2.24.1 Fire control plans are to meet the requirements of Ch 4,5.

■ *Section 3* Fire safety measures for yachts 500 gt or more

3.1 General

3.1.1 Table 3.3.1 is a guide to the major requirements of this Section. The Table is intended as a quick reference to the requirements and is not to be used in isolation when designing the fire safety arrangements.

3.2 Forms of construction – Structure

3.2.1 The hull, superstructure, structural bulkheads, decks and deckhouses may be constructed of steel, other equivalent material, *see* Ch 1,2.1.2 or be of alternative forms of construction, *see* Ch 1,2.1.3.

Table 3.3.1 General fire protection, detection and extinction requirements

Form of construction, *see* 3.2	Steel or equivalent, or alternative forms of construction may be accepted subject to extensive insulation requirements
Passive fire protection, *see* 3.3 to 3.12	*See* Table 3.3.2 and Table 3.3.3
Means of escape, *see* 3.15: • Category 'A' machinery spaces • Accommodation, etc.	} 2
Fixed fire detection system, *see* 3.24	• Fitted in machinery spaces • Fitted in service spaces, control stations and accommodation spaces
Fire pumps, *see* 3.25.1 to 3.25.10	• In general, 2 independent power pumps • For yachts of ≥4000 gross tons: 3 independent power pumps • A fire in any one compartment is not to put all the fire pumps out of action
International shore connection, *see* 3.25.11	At least 1
Fire extinguishing arrangements in Category 'A' machinery spaces, *see* 3.26. *See also* 3.27 for oil fuel units	• A fixed fire extinguishing system • Portable air-foam equipment • 45 litre foam extinguisher • Portable foam extinguishers within 10 m walking distance
Portable fire-extinguishers in accommodation, *see* 3.32	Sufficient to ensure that at least one will be readily available in every compartment, but a minimum of five
Automatic sprinkler system or equivalent, *see* 3.29	Fitted in all yachts
Fireman's outfits, *see* 3.38	At least 2

3.2.2 The structure in way of Category 'A' machinery spaces, galleys containing appliances of significant fire risk and other high risk areas is to be protected such that the material by itself or due to insulation provided can maintain its required strength at the end of 60 minutes exposure to the standard fire test.

3.2.3 Details of the method of construction, supported by calculations and/or fire test data, demonstrating compliance with 3.2.2 are to be submitted.

3.2.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the specified fire exposure.

3.2.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the specified fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.2.6 For structures in contact with sea-water, the required insulation should extend to at least 300 mm below the lightest waterline, *see also* 2.6.1.

3.3 Forms of construction – Fire divisions

3.3.1 Fire divisions required by 3.4 are to be constructed in accordance with the remaining paragraphs of 3.3.

3.3.2 Fire divisions using steel equivalent, or alternative forms of construction, may be accepted if it can be demonstrated that the material by itself due to insulation provided, has the fire resistance properties equivalent to 'A' or 'B' Class divisions.

3.3.3 Insulation required by 3.3.2 is to be such that the temperature of the structural core does not rise above the point at which the structure would begin to lose its strength at any time during the applicable exposure to the standard fire test. For 'A' Class divisions, the applicable exposure is 60 minutes, and for 'B' Class divisions, the applicable exposure is 30 minutes.

3.3.4 For aluminium alloy structures, the insulation is to be such that the temperature of the structural core does not rise more than 200°C above the ambient temperature at any time during the applicable fire exposure.

3.3.5 For composite structures, the insulation is to be such that the temperature of the laminate does not rise more than the minimum temperature of deflection under load of the resin at any time during the applicable fire exposure. The temperature of deflection under load is to be determined as in Ch 14,3.7 of the Rules for Materials.

3.4 Structural fire protection – Main vertical zones and horizontal zones

3.4.1 The hull, superstructure and deckhouses in way of accommodation and service spaces are to be subdivided into main vertical zones by 'A' Class divisions, *see* Ch 1,2.4.12. These divisions are to have insulation values in accordance with Tables 3.3.2 and 3.3.3.

3.4.2 As far as practicable, the bulkheads forming the boundaries of the main vertical zones above the bulkhead deck are to be in line with watertight subdivision bulkheads situated immediately below the bulkhead deck.

3.4.3 The bulkheads mentioned in 3.4.2 are to extend from deck to deck and to the shell or other boundaries.

Table 3.3.2 Fire integrity of bulkheads separating adjacent spaces

Spaces		*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Control stations	*(1)*	‘A-0’ *See* Note 3	‘A-0’	‘A-60’	‘A-0’	‘A-15’	‘A-60’	‘A-15’	‘A-60’	*See* Note 7
Corridors	*(2)*	—	C *See* Note 4	‘B-0’ *See* Note 4	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘B-0’ *See* Note 4	‘A-60’	‘A-0’	‘A-15’ ‘A-0’ *See* Note 6	*See* Note 7
Accommodation spaces	*(3)*	—	—	C *See* Note 4	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘B-0’ *See* Note 4	‘A-60’	‘A-0’	‘A-15’ ‘A-0’ *See* Note 6	*See* Note 7
Stairways	*(4)*	—	—	—	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘A-0’ *See* Note 1 ‘B-0’ *See* Note 4	‘A-60’	‘A-0’	‘A-15’ ‘A-0’ *See* Note 6	*See* Note 7
Service spaces (low risk)	*(5)*	—	—	—	—	C *See* Note 4	‘A-60’	‘A-0’	‘A-0’	*See* Note 7
Machinery spaces of Category ‘A’ and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels	*(6)*	—	—	—	—	—	‘A-60’ *See* Note 2	‘A-0’	‘A-60’	*See* Note 7
Other machinery spaces	*(7)*	—	—	—	—	—	—	‘A-0’ *See* Note 2	‘A-0’	*See* Note 7
Service spaces (high risk)	*(8)*	—	—	—	—	—	—	—	‘A-0’ *See* Note 2	*See* Note 7
Open decks	*(9)*	—	—	—	—	—	—	—	—	—

NOTES
1. For clarification as to which applies, *see* 3.7.
2. Where spaces are of the same numerical category and Note 2 appears, a bulkhead or deck of the ratings shown in the Table is only required when the adjacent spaces are for a different purpose, e.g. in category (8), a galley next to a galley does not require a bulkhead, but a galley next to a paint room requires an ‘A-0’ Class bulkhead.
3. Bulkheads separating the wheelhouse and chartroom from each other may be ‘B-0’ rating.
4. For the application of 3.4.1 all ‘B-0’ and ‘C’ Class bulkheads where appearing in this Table are to be taken as 'A-0' Class.
5. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
6. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be ‘A-0’ Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
7. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of ‘A’ Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.
8. For requirements for main vertical zones, *see* 3.4.1.

3.5 Structural fire protection of bulkheads within a main vertical zone

3.5.1 All such divisions may be faced with combustible materials.

3.5.2 When continuous ‘B’ Class ceilings and/or linings are fitted on both sides of the bulkhead, the portion of the bulkhead behind the continuous ceiling or lining is to be of material which in thickness and composition is acceptable in the construction of ‘B’ Class divisions but which may meet ‘B’ Class standards only insofar as is reasonable and practicable.

3.5.3 All bulkheads required to be ‘B’ Class divisions, except corridor bulkheads prescribed in 3.5.2, are to extend from deck to deck and to the shell or other boundaries unless continuous ‘B’ Class ceilings or linings fitted on both sides of the bulkhead are at least of the same fire resistance as the bulkhead, in which case the bulkhead may terminate at the continuous ceiling or lining.

3.6 Structural fire protection – Fire integrity of bulkheads and decks

3.6.1 In addition to complying with the specific provisions for fire integrity of bulkheads and decks mentioned elsewhere in this Section the minimum fire integrity of bulkheads and decks are to be as prescribed in Tables 3.3.2 and Table 3.3.3.

Table 3.3.3 **Fire integrity of decks separating adjacent spaces**

	Space above								
Space below	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*	*(6)*	*(7)*	*(8)*	*(9)*
Control stations *(1)*	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Corridors *(2)*	'A-0'	*See* Note 3	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Accommodation spaces *(3)*	'A-60'	'A-0'	*See* Note 3	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Stairways *(4)*	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Service spaces (low risk) *(5)*	'A-15'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-60'	'A-0'	'A-0'	*See* Note 3
Machinery spaces of Category 'A' and spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels *(6)*	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60'	'A-60' *See* Note 1	'A-60'	*See* Note 3
Other machinery spaces *(7)*	'A-15'	'A-0'	'A-0'	'A-0'	'A-0'	'A-0'	*See* Note 3	'A-0'	*See* Note 3
Service spaces (high risk) *(8)*	'A-60' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30' 'A-0' *See* Note 2	'A-30'	'A-0'	'A-60'	'A-0'	'A-0'	*See* Note 3
Open decks *(9)*	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	*See* Note 3	—

NOTE
1. Fire insulation need not be fitted if the machinery space of category (7) has little or no fire risk.
2. Where the spaces are protected by the sprinkler system on both sides of the division, the division may be 'A-0' Class. Where the sprinkler system only protects a space on one side of the division the rating is to be the higher of the two values given.
3. The division is to be of steel, other equivalent material, or alternative forms of construction, but is not required to be of 'A' Class standard. However, where decks, except open decks, are penetrated for the passage of electric cables, pipes and vent ducts, such penetrations are to be made tight to prevent the passage of flame and smoke.

3.6.2 For determining the appropriate fire integrity standards to be applied to divisions between adjacent spaces, such spaces are classified in Table 3.3.2 and Table 3.3.3 according to their fire-risk as shown in space categories ***(1)*** to ***(9)***. The title of each category is intended to be typical (general) rather than restrictive. The number in parentheses preceding each space category refers to the applicable column or row in the Tables.

(1) Control stations:
- Spaces containing emergency sources of power and lighting.
- Wheelhouse and chartroom.
- Spaces containing the ship's radio equipment.
- Fire-extinguishing rooms, fire-control stations and fire recording stations.
- Control room for propulsion machinery when located outside the machinery space.
- Spaces containing centralised fire-alarm equipment.

(2) Corridors:
- Guest and crew corridors and lobbies.

(3) Accommodation spaces:
- Spaces as defined in Ch 1,2.4.5 excluding corridors.

(4) Stairways:
- Interior stairways, lifts and escalators (other than those wholly contained within the machinery spaces) and enclosures thereto.
- In this connection, a stairway which is enclosed only at one level is to be regarded as part of the space from which it is not separated by a fire door.

(5) Service spaces (low risk):
- Lockers and store-rooms having areas of less than 4 m^2, drying rooms and laundries.

(6) Category 'A' machinery spaces, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels:
- Spaces as defined in Ch 1,2.4.8.

(7) Other machinery spaces:
- Spaces as defined in Ch 1,2.4.9 excluding Category 'A' machinery spaces.

(8) Service spaces (high risk):
- Galleys, pantries containing cooking appliances, paint and lamp rooms, lockers and store-rooms having areas of 4 m^2 or more, spaces for the storage of flammable liquids, bonded stores and workshops other than those forming part of the machinery spaces.

(9) Open decks:
- Open deck spaces and enclosed promenades having no fire-risk. Air spaces (the space outside superstructures and deckhouses).

3.6.3 Continuous 'B' Class ceilings or linings, in association with the relevant decks or bulkheads, may be accepted as contributing, wholly or in part, to the required insulation and integrity of a division.

3.7 Structural fire protection – Protection of stairways and lifts in accommodation and service spaces

3.7.1 All stairways are to be of steel construction except where the use of other equivalent material is specially approved, and are to be within enclosures formed of 'A' Class divisions, with positive means of closure at all openings, except that:

(a) A stairway connecting only two decks need not be enclosed, provided that the integrity of the deck is maintained by proper bulkheads or doors at one level to at least 'B-0' Class. When a stairway is closed at one level, the stairway enclosure is to be protected in accordance with Tables 3.3.2 and 3.3.3; and

(b) Stairways may be fitted in the open in a public space, provided that they lie wholly within such public space.

3.7.2 Stairway enclosures are to have a direct access to the corridors and to be of sufficient area to prevent congestion, having in view the number of persons likely to use them in an emergency. Within the perimeter of such stairway enclosures, only toilets and lockers of non-combustible material providing storage for safety equipment are permitted. Only public spaces, corridors, other escape stairways required by 3.15.1(e), pantries containing cooking appliances with an insignificant fire risk, *see* 2.4.2, and external areas are to have direct access to these stairway enclosures. Small corridors or lobbies may be used to separate an enclosed stairway from other spaces.

3.7.3 Lift trunks are to be so fitted as to prevent the passage of smoke and flame from one 'tween deck to another and are to be provided with means of closing so as to permit the control of draught and smoke.

3.8 Structural fire protection – Openings in 'A' Class divisions

3.8.1 The construction of all doors and door frames in 'A' Class divisions, and the means of securing them when closed, is to provide resistance to fire as well as to the passage of smoke and flame, as far as practicable, equivalent to that of the bulkheads in which the doors are situated. Such doors and door frames are to be constructed of steel or other equivalent material. Steel watertight doors need not be insulated.

3.8.2 It is to be possible for each door to be opened and closed from each side of the bulkhead by one person only.

3.8.3 Fire doors in main vertical zone bulkheads and stairway enclosures are to satisfy the following requirements:

(a) The doors shall be self-closing and be capable of closing with an angle of inclination of up to 3,5° opposing closure. The approximate time of closure for hinged fire-doors is to be no more than 40 s and not less than 10 s from the beginning of their movement with the ship in the upright position. The approximate uniform rate of closure for sliding fire doors is to be no more than 0,2 m/s and no less than 0,1 m/s with the ship in the upright position.

(b) Remote-controlled sliding or power-operated doors are to be equipped with an alarm that will sound not less than 5 s but no more than 10 s before the door begins to move and will continue to sound until the door is completely closed. Doors designed to re-open upon contacting an object in its path are to re-open sufficiently to allow a clear passage of at least 0,75 m but not more than 1 m.

(c) All doors are to be capable of remote and automatic release from the continuously manned central control station, either simultaneously or in groups and also individually from a position at both sides of the door. Indication is to be provided at the fire control panel in the continuously manned central control station whether each of the remotely-controlled doors are closed. The release mechanism is to be so designed that the door will automatically close in the event of disruption of the control system or central power supply. Release switches shall have an on-off function to prevent automatic resetting of the system. Hold-back devices not subject to central control station release are not permitted.

(d) Local power accumulators for power-operated doors are to be located in the immediate vicinity of the doors. They are to have the capacity to enable the doors to be fully opened and closed at least 10 times using local controls.

(e) Double-leaf doors dependent on a latch to maintain their fire integrity are to be arranged so that the latch is automatically activated by the action of the closing doors.

(f) Doors which are power-operated and automatically closed, giving direct access to special category spaces need not be equipped with the alarms and remote release mechanisms required by (b) and (c).

(g) The components of the local control system are to be accessible for maintenance and adjusting.

3.8.4 Where 'A' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for girders, beams or other structural members, arrangements are to be made to ensure that the fire resistance is not impaired.

3.9 Structural fire protection – Openings in steel outer boundaries

3.9.1 The requirements for steel or other equivalent material on the outer boundaries of a yacht do not apply to glass partitions, windows and sidescuttles. The requirements of 3.11.2 for such boundaries to have 'A' class integrity are to be adhered to.

3.10 Structural fire protection – Openings in 'B' Class divisions

3.10.1 Doors and door frames in 'B' Class divisions and means of securing them are to provide a method of closure which has resistance to fire as far as practicable equivalent to the divisions they serve, except that ventilation openings may be permitted in the lower portion of such doors. Where such openings are in or under a door the total net area of any such opening or openings is not to exceed 0,05 m^2. When such an opening is cut in a door it is to be fitted with a grill made of non-combustible material. Bridging ducts are not allowed in fire divisions.

3.10.2 Cabin doors in 'B' class divisions are to be self-closing. Hold-backs are not permitted.

3.10.3 Where 'B' Class divisions are penetrated for the passage of electric cables, pipes, trunks, ducts, etc., or for the fitting of ventilation terminals, lighting fixtures and similar devices, arrangements are to be made to ensure that the fire resistance is not impaired.

3.11 Structural fire protection – Windows and side scuttles

3.11.1 Notwithstanding the requirements of Table 3.3.2 and Table 3.3.3, all windows and side scuttles in bulkheads separating accommodation and service spaces and control stations from weather are to be constructed with frames of steel or other suitable material. The glass is to be retained by a metal glazing bead or angle. Alternative forms of construction and retention will be considered.

3.11.2 Glass is not to be installed as an interior main vertical zone or stairway enclosure bulkhead.

3.11.3 For yachts having a freeboard length of 85 m and over, windows and side scuttles situated in the yacht's side shell below the life raft and escape slide embarkation areas and below lifeboat embarkation areas are to have fire integrity of at least equal to 'A-0' Class.

3.12 Structural fire protection – Details of construction

3.12.1 In accommodation and services spaces, control stations, corridors and stairways, air spaces enclosed behind ceilings, panelling or linings are to be suitably divided by close-fitting draught stops not more than 7 m apart. In the vertical direction, such spaces, including those behind linings of stairways, trunks, etc., are to be closed at each deck.

3.12.2 The draught stops are to be non-combustible and are to form a continuation above the ceiling of the bulkhead below or the other side of the panelling or lining to the bulkhead, as far as possible.

3.12.3 Where the structure or 'A' Class divisions are required to be insulated, it is to be ensured that the heat from a fire is not transmitted through the intersections and terminal points of the divisions or penetrations to uninsulated boundaries. Where the insulation installed does not achieve this, arrangements are to be made to prevent this heat transmission by insulating the horizontal and vertical boundaries or penetrations for a distance of 450 mm.

3.13 Structural fire protection – Materials

3.13.1 Except in cargo spaces, mail rooms, baggage rooms, or refrigerated compartments, of service spaces, all insulation (e.g. fire and comfort) is to be of non-combustible materials. Partial bulkheads or decks used to subdivide a space for utility or artistic treatment are to have a non-combustible core.

3.13.2 The use of combustible materials is to be kept to a minimum.

3.13.3 Pipes penetrating 'A' or 'B' Class divisions are to be of approved materials having regard to the temperature such divisions are required to withstand.

3.13.4 Pipes conveying oil or combustible liquids through accommodation and service spaces are to be of approved materials having regard to the fire risk.

3.13.5 Materials readily rendered ineffective by heat are not to be used for overboard scuppers, sanitary discharges and other outlets which are close to the waterline and where the failure of the material in the event of fire would give rise to danger of flooding.

3.13.6 Primary deck coverings within accommodation spaces, service spaces and control stations are to be of a type which will not readily ignite, or give rise to toxic or explosive hazards at elevated temperatures. Reference is also to be made to the IMO FTP Code, Annex 1, Parts 2 and 6.

3.13.7 Vapour barriers and adhesives used in conjunction with insulation, as well as insulation of pipe fittings for cold service systems need not be non-combustible, but they shall be kept to the minimum quantity practicable and their exposed surfaces shall have low flame spread characteristics.

3.13.8 All waste receptacles are to be constructed of non-combustible materials with no openings in the sides or bottom.

3.13.9 Furniture in the stairway enclosures is to be limited to seating. If required, it is to be fixed, limited to four seats on each deck in each stairway enclosure and is not to obstruct the escape route. Additional seating may be permitted in the main reception area within a stairway enclosure provided it is fixed and does not obstruct the escape route. Furniture is not permitted in corridors forming escape routes in cabin areas. Lockers for the storage of safety equipment may be permitted.

3.14 Structural fire protection – Surface of insulation

3.14.1 In spaces where penetration of oil products is possible, the surface of insulation is to be impervious to oil or oil vapours. Insulation boundaries are to be arranged to avoid immersion in oil spillages so far as is practicable.

3.15 Structural fire protection – Means of escape

3.15.1 Stairways and ladders are to be arranged to provide ready means of escape to the survival craft embarkation deck from all guest and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces. In particular, the following provisions are to be complied with:

(a) Below the bulkhead deck, two means of escape, at least one of which is to be independent of watertight doors, are to be provided for each watertight compartment or similarly restricted space or group of spaces. One of these means of escape may be dispensed with, due regard being paid to the nature and the location of spaces concerned, and to the number of persons who normally might be accommodated or employed there.

(b) Above the bulkhead deck, there are to be at least two practical means of escape from each main vertical zone or similarly restricted space or group of spaces, at least one of which is to give access to a stairway forming a vertical escape.

(c) If a radio-telegraph station has no direct access to the open deck, two means of escape from or access to such station are to be provided, one of which may be a porthole or window of sufficient size or other satisfactory means to provide an emergency escape.

(d) A corridor, lobby, or part of a corridor from which there is only one route of escape is not to exceed 7 m. Where accommodation arrangements are such that access to compartments is through another compartment, as is often the case with an Owner's suite, a second means of escape is to be provided. The second escape route is to be as remote as possible from the main escape route. The second means of escape may be through portholes or hatches of adequate size, leading to the open deck.

(e) At least one of the means of escape required by (a) or (b) is to be by means of a readily accessible enclosed stairway, which will provide continuous fire shelter from the level of its origin to the appropriate survival craft embarkation decks, or the uppermost weather deck if the embarkation deck does not extend to the main vertical zone being considered. In the latter case, direct access to the embarkation deck by external open stairways and passageways is to be provided and is to have emergency lighting and slip-free surfaces underfoot. Boundaries facing external open stairways and passageways forming part of an escape route and boundaries in such a position that their failure during a fire would impede escape to the embarkation deck, are to have fire integrity and insulation values in accordance with Tables 3.3.2 and 3.3.3. The widths, number and continuity of escape routes are to be as follows:

    (i) Stairways are to be not less than 900 mm clear width between handrails. Stairways are to be fitted with handrails on each side. The minimum clear width of stairways is to be increased by 10 mm for every person provided for in excess of 90 persons. The maximum clear width between handrails where stairways are wider than 900 mm is to be 1800 mm. The total number of persons to be evacuated by such stairways is to be two-thirds of the crew and total number of passengers in the areas served by such stairways.

    (ii) Stairways with a clear width in excess of 900 mm are to be aligned in a fore-and-aft direction.

    (iii) Doorways, corridors and intermediate landings included in the means of escape are to have widths sized in the same manner as the stairways.

    (iv) Stairways are not to exceed 3,5 m vertical rise without the provision of a landing and are not to have angle of inclination greater than 45° to the horizontal.

    (v) Landings at each deck level are to be not less than 2 m^2 in area and are to be increased by 1 m^2 for every 10 persons provided for in excess of 20 persons but need not exceed 16 m^2, except for those landings serving public spaces having direct access onto the stairway enclosure.

(f) Protection of access from the stairway enclosures to the survival craft embarkation areas are to comply with the requirements of Tables 3.3.2 and 3.3.3.

(g) Where public spaces span three or more open decks, contain combustibles such as furniture and give access to other enclosed spaces, each level within the space is to have two means of escape, one of which is to give direct access to an enclosed vertical means of escape meeting the requirements of (e).

(h) Where a dispensation has been granted under the provisions of (a), a safe means of escape is to be provided. Stairways are to be provided with handrails on both sides and are to have a clear width between handrails of not less than 800 mm.

3.15.2 Two means of escape are to be provided from each machinery space. In particular, the following provisions are to be complied with:

(a) Where the space is below the bulkhead deck the two means of escape are to consist of either:

    (i) Two sets of steel ladders and walkways as widely separated as possible, leading to doors in the upper part of the space similarly separated and from which access is provided to the appropriate survival craft embarkation decks. One of these ladders is to provide continuous fire shelter from the lower part of the space to a safe position outside the space. This shelter is to be of steel or equivalent material, insulated where necessary, and provided with a self closing door of steel or equivalent material at the lower end. If access is provided at other levels each level is to be provided with a door of steel or equivalent material; or

    (ii) one steel ladder leading to a door in the upper part of the space from which access is provided to the embarkation deck and additionally, in the lower part of the space and in a position well separated from the ladder referred to, a steel or equivalent material door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the embarkation deck.

(b) Where the space is above the bulkhead deck, the two means of escape are to be as widely separated as possible and the doors leading from such means of escape are to be in positions from which access is provided to the appropriate survival craft embarkation decks. Where such means of escape require the use of ladders these are to be of steel.

3.15.3 One of the means of escape from any such space required by 3.15.2 may be dispensed with, so long as either a door or a steel ladder and walkways provides a safe escape route to the embarkation deck, due regard being paid to the nature and location of the space and whether persons are normally employed in that space.

3.15.4 Two means of escape are to be provided from a machinery control room located inside a machinery space, at least one of which is to provide continuous fire shelter to a safe position outside the machinery space.

3.15.5 Adequate deck area is to be provided at muster stations and embarkation areas having due regard to the expected number of persons.

3.16 Ventilation systems

3.16.1 Ventilation ducts are to be of non-combustible material. Short lengths of ducts not exceeding 2 m in length and with a cross-section not exceeding 0,02 m^2 need not be non-combustible, subject to these ducts being:

(a) of a material that has low flame spread characteristics;
(b) used at the end of the ventilation device; and
(c) situated not less than 600 mm, measured along the duct, from an opening in an ‘A’ or ‘B’ Class division including continuous ‘B’ Class ceilings.

3.16.2 Where the ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 pass through Class ‘A’ bulkheads or decks, the openings are to be lined with a steel sheet sleeve unless the ducts passing through the bulkheads or decks are of steel in the vicinity of passage through the deck or bulkhead and the ducts and sleeves are to comply in this part with the following:

(a) Steel ducts, or sleeves lining such ducts, are to have a thickness of at least 3 mm and a length of at least 900 mm. When passing through bulkheads, this length is to be divided preferably into 450 mm on each side of the bulkhead. These ducts, or sleeves lining such ducts, are to be provided with fire insulation. The insulation is to have at least the same fire integrity as the bulkhead or deck through which the duct passes.
(b) Steel ducts with a free cross-sectional area exceeding 0,075 m^2 are to be fitted with fire dampers in addition to the requirements of (a). The fire damper is to operate automatically but is also to be capable of being closed manually from both sides of the bulkhead or deck. The damper is to be provided with an indicator which shows whether the damper is open or closed. Fire dampers are not required, however, where ducts pass through spaces surrounded by ‘A’ Class divisions, without serving those spaces, provided those ducts have the same fire integrity as the divisions which they pierce.
(c) Compliance with 3.8.4.

3.16.3 Ventilation ducts with a free cross-sectional area exceeding 0,02 m^2 passing through ‘B’ Class bulkheads are to be lined with steel sheet, or other equivalent material, sleeves of 900 mm in length divided preferably into 450 mm on each side of the bulkheads unless the duct is of steel for this length, *see also* 3.10.3.

3.16.4 Ducts provided for the ventilation of Category ‘A’ machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, are not to pass through accommodation spaces, service spaces or control stations unless the ducts are:

(a) either:
  (i) constructed of steel having a thickness of at least 3 mm and 5 mm for ducts the widths or diameters of up to and including 300 mm and 760 mm and over respectively and, in the case of such ducts, the widths or diameters of between 300 mm and 760 mm having a thickness to be obtained by interpolation;
  (ii) suitably supported and stiffened;
  (iii) fitted with automatic fire dampers close to the boundaries penetrated; and
  (iv) insulated to ‘A-60’ Class standard from the machinery spaces, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, to a point at least 5 m beyond each fire damper;
(b) or:
  (i) constructed of steel in accordance with (a)(i) and (ii); and
  (ii) insulated to ‘A-60’ Class standard throughout the accommodation spaces, service spaces or control stations;

except that penetrations of main zone divisions are also to comply with 3.16.8.

3.16.5 Ducts provided for ventilation to accommodation spaces, service spaces or control stations are not to pass through such spaces, unless, where they pass through Category ‘A’ machinery space, galleys, spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels, the ducts:

(a) either:
  (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii);
  (ii) are fitted with automatic fire dampers close to the boundaries penetrated; and
  (iii) have the integrity of boundaries of the machinery space, galley, spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, maintained at the penetrations;
(b) or:
  (i) are constructed of steel in accordance with 3.16.4(a)(i) and (ii); and
  (ii) are insulated to ‘A-60’ Class standard within the machinery space, galley or spaces containing vehicles or craft with fuel in their tanks or lockers storing such fuels;

except that penetration of main zone divisions is also to comply with 3.16.8.

3.16.6 Such measures as are practicable are to be taken in respect of control stations outside machinery spaces in order to ensure that ventilation, visibility and freedom from smoke are maintained, so that in the event of fire the machinery and equipment contained therein may be supervised and continue to function effectively. Alternative and separate means of air supply are to be provided; air inlets of the two sources of supply are to be so disposed that the risk of both inlets drawing in smoke simultaneously is minimised. Such requirements need not apply to control stations situated on,

and opening on to, an open deck, or where local closing arrangements would be equally effective.

3.16.7 Where they pass through accommodation spaces or spaces containing combustible materials, the exhaust ducts from galley ranges are to comply with 3.16.4. Such exhaust ducts are to be fitted with:
(a) a grease trap readily removable for cleaning;
(b) a fire damper located in the lower end of the duct;
(c) arrangements, operable from within the galley, for shutting off the exhaust fans; and
(d) fixed means for extinguishing a fire within the duct.

3.16.8 Where it is necessary that a ventilation duct passes through a main vertical zone division, a fail-safe automatic closing fire damper is to be fitted adjacent to the division. The damper is also to be capable of being manually closed from each side of the division. The operating position is to be readily accessible and be marked in red light-reflecting colour. The duct between the division and the damper is to be of steel or other equivalent material and, if necessary, insulated to comply with 3.8.4. The damper is to be fitted on at least one side of the division with a visible indicator showing whether the damper is in the open position.

3.16.9 Where public spaces span three or more open decks and contain combustibles such as furniture and other enclosed spaces, the space is to be equipped with a smoke extraction system. The smoke extraction system is to be activated by the smoke detection system required by Ch 4,2 and is to be capable of manual control. The fans are to be capable of exhausting the entire volume within the space in not more than 10 min.

3.16.10 The main inlets and outlets of all ventilation systems are to be capable of being closed from outside the spaces being ventilated.

3.16.11 Power ventilation of accommodation spaces, service spaces, control stations and machinery spaces is to be capable of being stopped from an easily accessible position outside the space being served. This position should not be readily cut off in the event of a fire in the spaces served. The means provided for stopping the power ventilation of the machinery spaces is to be entirely separate from the means provided for stopping ventilation of other spaces, *see also* Pt 16, Ch 2,17.6.

3.16.12 Reference is also made to 2.8.4 to 2.8.7, 2.8.9 and 3.10.1.

3.16.13 Ducts provided for exhaust ventilation from laundries are to be fitted with suitably located cleaning and inspection openings.

3.16.14 Fire dampers required by 3.16.2, 3.16.4, 3.16.5 and 3.16.8, including relevant means of operation are to be fire tested. Reference is also to be made to IMO FTP Code, Annex 1, Part 3.

3.17 Oil fuel arrangements

3.17.1 In a yacht in which oil fuel is used, the arrangements for the storage, distribution and utilisation of the oil fuel are to be such as to ensure the safety of the yacht and persons on board. For details, *see* Pt 15, Ch 3.

3.17.2 As far as practicable, oil fuel tanks are to be part of the yacht's structure and are to be located outside Category 'A' machinery spaces.

3.17.3 Where oil fuel tanks, other than double bottom tanks, are necessarily located adjacent to or within Category 'A' machinery spaces, at least one of their vertical sides is to be contiguous to the machinery space boundaries, and is preferably to have a common boundary with the double bottom tanks, and the area of the tank boundary common with the machinery spaces is to be kept to a minimum. Where the vertical boundary of a tank directly exposed to a machinery space meets the yacht's side plating at an acute angle, a small horizontal surface at the base of the tank, necessary to accommodate practical constructional considerations may be permitted. If the arrangement of the machinery is such that a tank with a large horizontal surface at the base is necessary then a cofferdam with suitable ventilation arrangements, to protect the base of the tank from the effect of a machinery space fire, will be specially considered. *See also* Pt 15, Ch 3. Oil fuel tanks situated within the boundaries of Category 'A' machinery spaces are not to contain oil fuel having a flashpoint of less than 60°C. The use of free-standing oil fuel tanks is prohibited.

3.18 Lubricating oil arrangements

3.18.1 The arrangements for the storage, distribution and utilisation of oil used in pressure lubrication systems are to be such as to ensure the safety of the yacht and persons on board, *see also* Pt 15, Ch 3.

3.19 Arrangements for other flammable oils

3.19.1 The arrangements for the storage, distribution and utilisation of other flammable oils employed under pressure in power transmission systems, control and activating systems and heating systems are to be such as to ensure the safety of the ship and persons on board, *see also* Pt 15, Ch 3.

3.20 Prohibition of carriage of flammable oils in forepeak tanks

3.20.1 Oil fuel, lubricating oil and other flammable oils are not to be carried in forepeak tanks.

3.21 Special arrangements in Category 'A' machinery spaces

3.21.1 Openings are to be provided with closing appliances constructed so as to maintain the fire integrity of the machinery space boundaries.

3.21.2 Doors other than power operated watertight doors, are to be so arranged that positive closure is assured in case of fire in the space, by power-operated closing arrangements or by the provision of self-closing doors capable of closing against an inclination of 3,5° opposing closure and having a fail-safe hook-back facility, provided with a remotely operated release device.

3.21.3 Windows are not to be fitted in machinery space boundaries. This does not preclude the use of glass in control rooms within the machinery spaces.

3.21.4 Means of control are to be provided for:

(a) closure of openings which normally allow exhaust ventilation, and closure of ventilator dampers;
(b) permitting the release of smoke;
(c) closing power-operated doors or actuating release mechanism on doors other than power-operated watertight doors;
(d) stopping ventilating fans; and
(e) stopping forced and induced draught fans, oil fuel transfer pumps, oil fuel unit pumps and other similar fuel pumps.

3.21.5 The controls required in 3.21.4 are to be located outside the space concerned, where they will not be cut off in the event of fire in the space they serve. Such controls and the controls for any required fire-extinguishing system are to be situated at one control position or grouped in as few positions as possible. Such positions are to have a safe access from the open deck, *see also* Pt 15, Ch 3,4.5.1 and 4.9.2.

3.21.6 When access to any Category 'A' machinery space is provided at a low level from an adjacent space there is to be provided near the watertight door, a light steel fire-screen door operable from each side.

3.22 Arrangements for gaseous fuel for domestic purposes

3.22.1 Where gaseous fuel is used for domestic purposes, the arrangements for the storage, distribution and utilisation of the fuel is to be such that, having regard to the hazards of fire and explosion which the use of such fuel may entail, the safety of the yacht and the persons on board is preserved. The installation is to be in accordance with recognised National or International Standards.

3.22.2 Storage lockers for gas cylinders are to be provided with:

(a) effective ventilation;
(b) an outward-opening door accessible directly to the open deck; and
(c) gas-tight boundaries, including doors and other means of closing any openings therein, which form boundaries between such lockers and adjoining enclosed spaces.

3.23 Space heaters

3.23.1 Space heaters, if used, are to be fixed in position and so constructed as to reduce fire risks to a minimum. The design and location of these units are to be such that clothing, curtains or other similar materials cannot be scorched or set on fire by heat from the unit.

3.24 Fixed fire detection and fire-alarm systems

3.24.1 A fixed fire detection and fire-alarm system is to be installed in any machinery space and is to comply with the requirements of Pt 16, Ch 1,2.8.

3.24.2 A fixed fire detection and fire-alarm system is to be fitted in all stairways (including lift and dumbwaiter trunks), service spaces, control stations and accommodation spaces (except toilets, bathrooms, void spaces, etc.). The fixed fire detection and fire-alarm system is to be installed in accordance with Ch 4,2.

3.24.3 All yachts at all times when at sea, or in port (except when out of service), are to be so equipped as to ensure that any initial fire-alarm is immediately received by a responsible member of the crew.

3.24.4 A special alarm, operated from the navigating bridge or fire-control station, is to be fitted to summon the crew.

3.24.5 For yachts having a freeboard length of 85 m or more, a public address system is to be available throughout the accommodation spaces, service, and control stations and open decks. The arrangements are to comply with Pt 16, Ch 2,18.3.

3.25 Fire pumps and fire main system

3.25.1 **Application**. Every yacht is to be provided with fire pumps in accordance with this Section. Fire mains, hydrants and hoses are also to be provided as required by this Section.

3.25.2 **Capacity of fire pumps**:

(a) The fire pumps required are to be capable of delivering for fire-fighting purposes a quantity of water, at the pressure specified in 3.25.5 of not less than two-thirds of the quantity required to be dealt with by the bilge pumps when employed for bilge pumping. For number and capacity of bilge pumps, *see* Pt 15, Ch 2.
(b) As an alternative to (a) the capacity of fire pumps may be determined by hydrostatic calculations based on the requirement of 3.25.5(a).
(c) Where more pumps than the minimum number of required pumps are installed the capacity of such additional pumps will be specially considered.

3.25.3 **Fire pumps**:

(a) In yachts of 4000 tons gross or more, at least three independently driven fire pumps are to be provided and, in yachts of less than 4000 tons gross, at least two such fire pumps.
(b) Sanitary, ballast, bilge or general service pumps may be accepted as fire pumps, provided that they are not normally used for pumping oil, and that, if they are subject to occasional duty for the transfer or pumping of fuel oil, suitable changeover arrangements are fitted.

(c) In yachts classed for navigation in ice, the fire pump sea inlet valves are to be provided with clearing arrangements, *see* Pt 1, Ch 2,3.8.1.

(d) The arrangements of sea connections, fire pumps and their sources of power are to be such as to ensure that in the event of a fire in any one compartment, all the fire pumps will not be put out of action.

(e) The arrangements for the ready availability of water supply are to be as follows:

  (i) In yachts of 1000 gross tons or more, or any yacht of an alternative form of construction, the arrangements are to be such that at least one effective jet of water is immediately available from any hydrant in an interior location and so as to ensure the continuation of the output of water by the automatic starting of a required fire pump.

  (ii) Yachts not provided with arrangements complying with (i), but to which a UMS notation is to be assigned, are to have remote starting of a required fire pump from the navigating bridge and fire-control station, if any.

(f) Relief valves are to be provided in conjunction with any fire pump if the pump is capable of developing a pressure exceeding the design pressure of the water service pipes, hydrants and hoses. These valves are to be so placed and adjusted as to prevent excessive pressure in any part of the fire main system.

(g) Where centrifugal pumps are provided in order to comply with this sub-Section, a non-return valve is to be fitted in the pipe connecting the pump to the fire main.

3.25.4 **Fire main**:

(a) The diameter of the fire main is to be based on the required capacity of two fire pumps, and the diameter of the water service pipes are to be sufficient to ensure an adequate supply of water for the simultaneous operation of at least two fire-hoses. In general, the diameter of the fire main is to be not less than:

$$d = (L_{pp}/1{,}2) + 25 \text{ mm}$$

but need not exceed 180 mm in yachts, and is in no case to be less than 50 mm

where

d = internal diameter of the fire main, in mm

L_{pp} = length of yacht measured between perpendiculars, in metres, as defined in Pt 3, Ch 1,6.2.2.

(b) The wash deck line may be used as a fire main provided that the requirements of this sub-Section are satisfied.

(c) All exposed water pipes for fire-extinguishing are to be provided with drain valves for use in frosty weather. The valves are to be located where they will not be damaged.

3.25.5 **Pressure in the fire main**:

(a) The fire pumps, associated piping and fire main are to be so designed that the following minimum pressures will be maintained at all hydrants under conditions where two fire pumps required by 3.25.3 are simultaneously delivering water to the fire main of the size required by 3.25.4 through adjacent nozzles of sizes required by 3.25.9:

4000 tons gross and over	4 bar (0,4 N/mm^2)
Less than 4000 tons gross	3 bar (0,3 N/mm^2)

(b) The maximum pressure at any hydrant shall not exceed that at which the effective control of a fire-hose can be demonstrated.

3.25.6 **Number and position of hydrants**:

(a) The number and position of the hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which is to be from a single length of hose, may reach any part of the yacht normally accessible to the guests and crew while the yacht is being navigated. In yachts of 1000 tons gross or more, at least two hydrants are to be provided in the machinery spaces; in smaller yachts one hydrant will be accepted.

(b) In the accommodation, service and machinery spaces, the number and position of hydrants are to be such that the requirements of (a) may be complied with when all watertight doors and all doors in main vertical zone bulkheads are closed.

(c) Where access is provided to a machinery space of Category ‘A’ at a low level, two hydrants are to be provided external to, but near the entrance, to that machinery space.

3.25.7 **Pipes and hydrants**:

(a) Materials readily rendered ineffective by heat are not to be used for fire mains. Where steel pipes are used, they are to be galvanised internally and externally. Cast iron pipes are not acceptable. The pipes and hydrants are to be so placed that the fire-hoses may be easily coupled to them. The arrangement of pipes and hydrants is to be such as to avoid the possibility of freezing. Unless one hose and nozzle is provided for each hydrant in the yacht, there is to be complete interchangeability of hose couplings and nozzles.

(b) A valve is to be fitted at each fire hydrant so that any fire-hose may be removed while the fire pump is at work.

(c) Isolating valve(s) to isolate the section of the fire main within the Category ‘A’ machinery space containing the main fire pump(s) from the rest of the fire main are to be fitted in an easily accessible and tenable position outside the Category ‘A’ machinery space. The fire main is to be so arranged that when the isolating valve(s) is shut, all the hydrants on the yacht, except those in the Category ‘A’ machinery space referred to above, can be supplied with water by a fire pump not located in this Category ‘A’ machinery space through pipes which do not enter this space.

3.25.8 **Fire-hoses**:

(a) Fire-hoses are to be of approved non-perishable material. The hoses are to be sufficient in length to project a jet of water to any of the spaces in which they may be required to be used. Their length, in general, is not to exceed 18 m. Each hose is to be provided with a nozzle and the necessary couplings. Fire-hoses, together with any necessary fittings and tools, are to be kept ready for use in conspicuous positions near the water service hydrants or connections.

(b) There is to be at least one fire-hose for each of the hydrants required by 3.25.6.

3.25.9 **Nozzles**:

(a) For the purpose of this Chapter, standard nozzle sizes are to be 12 mm, 16 mm or 19 mm, or as near thereto as possible, so as to make full use of the maximum discharge capacity of the fire pumps.

(b) For accommodation and service spaces, the nozzle size need not exceed 12 mm.

(c) For machinery spaces and exterior locations, the nozzle size is to be such as to obtain the maximum discharge possible from two jets at the pressure indicated in 3.25.5 from the smallest pump, however a nozzle size greater than 19 mm need not be used.
(d) All nozzles are to be of an approved dual purpose type (i.e. spray/jet type) incorporating a shut-off.

3.25.10 **Location and arrangement of water pumps, etc., for other fire-extinguishing systems**. Pumps required for the provision of water for other fire-extinguishing systems required by this Chapter are to have their sources of power and their controls installed outside the space or spaces protected by such systems and are to be so arranged that a fire in the space or spaces protected will not put any such system out of action.

3.25.11 **International shore connection**. At least one international shore connection is to be provided.

3.26 Fire-extinguishing arrangements in spaces containing internal combustion machinery

3.26.1 Category 'A' machinery spaces containing internal combustion machinery are to be provided with:
(a) one of the fire-extinguishing systems described in Ch 4,3;
(b) at least one set of portable air-foam equipment complying with 3.29;
(c) in each such space approved foam type fire-extinguishers, each of at least 45 litres capacity or equivalent, sufficient in number to enable foam or its equivalent to be directed on to any part of the fuel and lubricating oil pressure systems, gearing and other fire hazards; and
(d) a sufficient number of portable foam extinguishers or equivalent are to be located so that no point in the space is more than 10 m walking distance from an extinguisher and that there are at least two such extinguishers in each such space.

3.26.2 Machinery spaces in yachts which are constructed mainly or wholly with alternative forms of construction, containing internal combustion machinery, are to comply with the requirements of 3.26.1.

3.27 Fire-extinguishing arrangements in spaces containing oil fuel units

3.27.1 Category 'A' machinery spaces containing oil fuel units are to be provided with one of the fixed fire-extinguishing systems described in Ch 4,3.

3.27.2 There are to be at least two portable foam extinguishers or equivalent in each space in which a part of the oil fuel unit is situated.

3.28 Limitations on the use of oil as a fuel

3.28.1 For the limitations of the use of oil as a fuel, *see* Pt 15, Ch 3.

3.29 Automatic sprinkler, fire detection and fire-alarm system

3.29.1 A fixed automatic sprinkler, fire detection and fire-alarm system, or equivalent system (e.g. watermist), is to be fitted in all stairways, service spaces, control stations and accommodation spaces except spaces which afford no fire risk such as void spaces.

3.29.2 The arrangements are to be in accordance with Ch 4,1.

3.30 Fixed fire-extinguishing systems not required by this Section

3.30.1 Where a fixed fire-extinguishing system not required by this Section is installed, the arrangement is to comply with the relevant requirements of this Chapter.

3.31 Portable foam applicator

3.31.1 A portable foam applicator unit is to consist of an air foam nozzle of an inductor type capable of being connected to the fire main by a fire-hose, together with a portable tank containing at least 20 litres of foam-making liquid and one spare tank. The nozzle is to be capable of producing effective foam, suitable for extinguishing an oil fire, at the rate of at least 1,5 m^3/min.

3.32 Portable fire-extinguishers

3.32.1 All fire-extinguishers are to comply with the requirements of Ch 4,6.

3.32.2 The extinguishers are to be stowed in readily accessible positions.

3.32.3 One of the portable fire-extinguishers, or the portable fire-extinguisher, dedicated for use in any space is to be stowed near the entrance to that space.

3.32.4 At least one portable fire-extinguisher is to be located so that it can easily be reached from the main steering position of the yacht.

3.32.5 Accommodation spaces, service spaces and control stations are to be provided with a sufficient number of portable fire-extinguishers to ensure that at least one extinguisher will be readily available for use in every compartment. In any case, their number is to be not less than five.

3.32.6 Where cooking facilities are provided, a portable fire-extinguisher of a type appropriate to the energy source used is to be located in a position readily accessible for use in the event of a fire.

3.33 Fire blanket

3.33.1 A fire blanket is to be installed in all galleys.

3.34 Protection of spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels

3.34.1 Spaces containing vehicles or craft with fuel in their tanks, or lockers storing such fuels, are to be provided with the following:

(a) A fixed fire detection and fire-alarm system complying with the requirements of Pt 16, Ch 1,2.8.

(b) A manually-operated water spray deluge system having a water application rate of 5 litres per square metre of deck area per minute. Where the deck height does not exceed 2,5 m, an application rate of 3,5 litres per square metre of deck area per minute will be accepted. Adequate drainage of the protected spaces is to be provided generally in accordance with the requirements for vehicle or cargo space, *see* Pt 3, Ch 4,9.4.4. The drainage piping and connections for the space are to be non-combustible. Other fixed fire-extinguishing systems may be permitted, provided they are not less effective in controlling the type of fire likely to occur.

(c) At least two portable foam extinguishers, or equivalent;

(d) An independent mechanical ventilation system , which is entirely separate from other ventilation systems, providing at least six air changes per hour. The ducted air is not to pass through other spaces, except as allowed under 3.16.4, or vent into areas where it could be drawn into accommodation areas or cause undue hazard.

(e) Electrical equipment of a safe type is to be provided, *see* Pt 16, Ch 2,14.

(f) Prominently displayed 'No Smoking' signs; and

(g) Structural fire protection as required by Table 3.3.2 and Table 3.3.3.

3.34.2 Such spaces are not to give access to any space other than the fuel store or lockers for use within the space. Lockers storing fuel are to be accessed from an exterior location, unless the locker is within the space containing the vehicles or craft. Exceptionally, where the engine room escape cannot be routed elsewhere, it may exit into the space providing that:

(a) the connecting door is self-closing;

(b) no door hold-back devices are fitted;

(c) an audible and visual alarm is fitted on the bridge to signify when the door is open; and

(d) a notice is posted at the door stating that the door is to remain closed and that the area beside the door is an escape route and is to be kept clear.

3.34.3 The requirements of 3.17 are to be complied with, as appropriate.

3.35 Protection of paint lockers and flammable liquid lockers

3.35.1 Paint lockers and flammable liquid lockers of deck area 4 m^2 or more are to be provided with a fixed fire-extinguishing system enabling the crew to extinguish a fire without entering the space. One of the following systems is to be provided:

- A carbon dioxide system designed for 40 per cent of the gross volume of the space.
- A dry powder system designed to discharge 0,5 kg powder per cubic metre of gross volume of the space.
- A water spray system designed to give a coverage of 5 litres per square metre of deck area per minute. Water spray systems may be connected to the fire main.

3.35.2 Consideration will be given to the acceptance of other arrangements which provide equivalent protection.

3.35.3 Lockers having a deck area less than 4 m^2 may be protected by carbon dioxide or dry powder portable extinguishers located near the entrance to the locker.

3.36 Arrangements where deep fat cooking equipment is installed

3.36.1 Where deep-fat cooking equipment is installed, all installations are to be fitted with:

(a) an automatic or manual fixed extinguishing system type approved in accordance with ISO 15371, *Ships and marine technology – Fire extinguishing systems for protection of galley deep-fat cooking equipment – Fire tests*, or an acceptable alternative National or International Standard, for protection of the deep-fat cooking equipment;

(b) a primary and back up thermostat with an alarm to alert the operator in the event of failure of either thermostat;

(c) arrangements for automatically shutting off the deep-fat cooking equipment electrical power upon activation of the fire-extinguishing system;

(d) an alarm for indicating operation of the fire-extinguishing system in the galley where the equipment is installed; and

(e) controls for manual operation of the fire-extinguishing system which are clearly labelled for ready use by the crew.

Control and electrical engineering arrangements are to be in accordance with the requirements of Pt 16, Ch 1 and Ch 2, as applicable.

3.36.2 For fryers of up to 15 litres cooking oil capacity, the provision of a suitably sized extinguisher of a suitable type located for specific use on the cooking equipment together with manual isolation of the electrical power supply may be considered an acceptable alternative to 3.36.1 provided the arrangements are to the satisfaction of the National Administration.

3.37 Helicopter decks

3.37.1 The requirements of IMO Resolution A.855(20) are to be complied with having due regard to the hazards involved.

3.37.2 If a helicopter hangar is not provided and if two fireman's outfits are supplied as per 3.38.1, then the fireman's outfits required by IMO Resolution A.855(20) need not be provided.

3.38 Fireman's outfit

3.38.1 Each yacht is to carry at least two fireman's outfits complying with Ch 4,4. Additional fireman's outfits are to be provided as applicable to ensure that at least two fireman's outfits are stored in each main vertical zone.

3.38.2 The fireman's outfits are to be so stored as to be easily accessible and ready for use. Where more than two fireman's outfits are required, they are to be located in widely separated positions. At least two fireman's outfits are to be available at any one position.

3.38.3 Additional sets of personal equipment and breathing apparatus, may be required, having due regard to the size of the yacht.

3.39 Fire-control plans

3.39.1 Fire-control plans are to meet the requirements of Ch 4,5.

Section

■ *Section 1* Automatic sprinkler, fire detection and fire-alarm systems

1.1 General

1.1.1 Any required automatic water sprinkler and fire-alarm and fire detection system is to be designed for immediate use at any time. Where such a system is fitted, it is to be of the wet pipe type. Any part of the system which may be subjected to freezing temperatures in service are to be suitably protected against freezing. It is to be kept charged at the necessary pressure and have provision for a continuous supply of water.

1.1.2 As an alternative to the system specified in 1.1.1, any one of the following systems may be considered:

(a) **Dry pipe system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air or nitrogen under pressure, the release of which (as from the opening of a sprinkler) permits the water pressure to open a valve known as a dry pipe valve. The water then flows into the piping system and out of the opened sprinklers.

(b) **Pre-action system**. A sprinkler system employing automatic sprinklers attached to a piping system containing air that may or may not be under pressure, with a supplemental detection system installed in the same area as the sprinklers. Actuation of the detection system opens a valve that permits water to flow into the sprinkler piping system and to be discharged from any sprinklers that may be open.

(c) **Deluge system**. A sprinkler system employing open sprinklers attached to a piping system connected to a water supply through a valve that is opened by the operation of a detection system installed in the same areas as the sprinklers. When this valve opens water flows into the piping system and discharges from all sprinklers attached thereto.

1.2 Wet pipe type

1.2.1 Any required automatic sprinkler, fire detection and fire-alarm system is to comply with the requirements of Pt 16, Ch 2,17.2.

1.2.2 Sprinklers are to be grouped into separate sections, each of which is to contain not more than 200 sprinklers. Any section of sprinklers is not to serve more than two decks nor be situated in more than one main vertical zone, except where it is satisfactorily shown that the protection of the yacht against fire will not thereby be reduced.

1.2.3 Each section of sprinklers is to be capable of being isolated by one stop valve only. The stop valve in each section is to be readily accessible and its location is to be clearly and permanently indicated. Means are to be provided to prevent the operation of the stop valves by any unauthorised person.

1.2.4 A gauge indicating the pressure in the system is to be provided at each section stop valve and at a central station.

1.2.5 The sprinklers are to be resistant to corrosion by marine atmosphere. In accommodation and service spaces the sprinklers are to come into operation within the temperature ranges from 68°C to 79°C, except that in locations such as drying rooms, where high ambient temperatures might be expected, the operating temperature may be increased by not more than 30°C above the maximum deck head temperature.

1.2.6 A list or plan is to be displayed at each indicating unit showing the spaces covered and the location of the zone in respect of each section. Suitable instructions for testing and maintenance are to be available.

1.2.7 Sprinklers are to be placed in an overhead position and spaced in a suitable pattern to maintain an average application rate of not less than 5 litres per square metre per minute over the nominal area covered by the sprinklers. The use of sprinklers providing other amounts of water suitably distributed, will be considered provided they are shown to be not less effective.

1.2.8 A pressure tank having a volume equal to at least twice that of the charge of water specified in 1.2.9 is to be provided.

1.2.9 The tank is to contain a standing charge of fresh water, equivalent to the amount of water which would be discharged in one minute by the pump referred to in 1.2.12, and the arrangements are to provide for maintaining such air pressure in the tank to ensure that where the standing charge of fresh water in the tank has been used the pressure will be not less than the working pressure of the sprinkler, plus the pressure exerted by a head of water measured from the bottom of the tank to the highest sprinkler in the system. Suitable means of replenishing the air under pressure and of replenishing the fresh water charge in the tank are to be provided. A glass gauge suitably protected is to be provided to indicate the correct level of the water in the tank.

1.2.10 Means are to be provided to prevent the passage of sea water into the tank.

1.2.11 An independent power pump is to be provided solely for the purpose of automatically continuing the discharge of water from the sprinklers. The pump is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

1.2.12 The pump and the piping system are to be capable of maintaining the necessary pressure at the level of the highest sprinkler to ensure a continuous output of water sufficient for the simultaneous coverage of a minimum area of the maximum width of the craft squared or 280 m^2 whichever is the less, at the application rate specified in 1.2.7.

1.2.13 The pump is to have fitted on the delivery side a test valve with a short open-ended discharge pipe. The effective area through the valve and pipe is to be adequate to permit the release of the required pump output while maintaining the pressure in the system specified in 1.2.9.

1.2.14 The sea inlet to the pump is to be, wherever possible, in the space containing the pump and is to be so arranged that when the vessel is afloat it will not be necessary to shut off the supply of sea water to the pump for any purpose other than the inspection or repair of the pump.

1.2.15 The sprinkler pump and tank are to be situated in a position reasonably remote from any machinery space of Category 'A' and not in any space required to be protected by the sprinkler system.

1.2.16 Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts of not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected by the system.

1.2.17 For yachts of not greater than 50 m Rule length and all service craft, the sources of electrical power supply for the sea-water pump may be fed from the main source of electrical power.

1.2.18 There are to be not less than two sources of power supply for the sea water pump and automatic alarm and detection system. Where one of the sources of power for the pump is an internal combustion engine it is to be so situated that a fire in any protected space will not affect the air supply to the machinery, in addition to complying with 1.2.15. When the sources of power for the pump are electrical, *see* Pt 16, Ch 2,2 and Pt 16, Ch 2,3.

1.2.19 The sprinkler system is to have a connection from the vessel's fire main by way of a lockable screw-down non-return valve at the connection which will prevent a backflow from the sprinkler system to the fire main.

1.2.20 A test valve is to be provided for testing the automatic alarm for each section of sprinklers by a discharge of water equivalent to the operation of one sprinkler. The test valve for each section is to be situated near the stop valve for that section.

1.2.21 Means are to be provided for testing the automatic operation of the pump, on reduction of pressure in the system.

1.2.22 Each section of sprinklers is to include means for giving a visual and audible alarm signal automatically at one or more indicating units whenever any sprinkler comes into operation. Such alarm systems are to be arranged to indicate if any fault occurs in the system. Such units are to indicate in which section, served by the system, fire has occurred and are to be centralised on the navigation bridge. In addition, visible and audible alarms from the unit are to be located in a position other than on the navigation bridge, so as to ensure that the indication of fire is immediately received by the crew. Switches are to be provided at one of these indicating positions, which will enable the alarm and the indicators for each section of sprinklers to be tested.

1.2.23 Spare sprinkler heads are to be provided as specified in Table 4.1.1. The spare sprinkler heads are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing sprinkler heads. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.1 Spares requirements

Number of sprinkler heads provided	Number of spare sprinkler heads required
300	One spare sprinkler head is to be provided for each 50 sprinkler heads fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

1.3 Arrangements which will be accepted as an alternative to 1.2

1.3.1 The alternative system is to be tested, type approved and installed in accordance with IMO Resolution A.800(19). The following exceptions to Section 3 of the Annex may be applied:

(a) Where the arrangement precludes locating the pump and tank in accordance with 1.2.15, for yachts not greater than 50 m Rule length, the sprinkler pump and tank required by Ch 3,2.16 may be situated within Category 'A' machinery spaces, but not within the spaces that are protected.

(b) Pumps and alternative supply components are to be sized so as to be capable of maintaining the required flow to the hydraulically most demanding area of not less than the maximum width of the craft squared or 280 m^2 whichever is the less.

1.3.2 Spare nozzles are to be provided as specified in Table 4.1.2. The spare nozzles are to be stowed in boxes or holders provided for that purpose, together with a tool suitable for removing and installing nozzles. The boxes or holders are to be situated near the control valve for the section, and are to be clearly and permanently marked to indicate their contents.

Table 4.1.2 Spares requirements

Number of nozzles provided	Number of spare nozzles required
300	One spare nozzle is to be provided for each 50 nozzles fitted, with a minimum of one spare being provided for each type fitted
301 to 1000	12
>1000	24

■ *Section 2* Fixed fire detection and fire-alarm systems

2.1 General requirements

2.1.1 Any required fixed fire detection and fire-alarm system with manually operated call points is to be capable of immediate operation at all times.

2.1.2 Fire detection systems are to comply with the requirements of Pt 16, Ch 2,17.1 in addition to the requirements of this Section.

2.1.3 Detectors are to be operated by heat, smoke or other products of combustion, flame, or any combination of these factors. Detectors operated by other factors indicative of incipient fires may be considered provided that they are no less sensitive than such detectors. Flame detectors are only to be used in addition to smoke or heat detectors.

2.1.4 Suitable instructions for testing and maintenance are to be provided.

2.1.5 For each type of detector installed, one spare detector head is to be provided for every 10 heads or part thereof. They are to be stowed in a suitable container at the control station.

2.1.6 The function of the detection system is to be periodically tested by means of equipment producing hot air at the appropriate temperature, or smoke or aerosol particles having the appropriate range of density or particle size, or other phenomena associated with incipient fires to which the detector is designed to respond. All detectors are to be of a type such that they can be tested for correct operation and restored to normal surveillance without the renewal of any component.

2.2 Installation requirements

2.2.1 Manually operated call points are to be installed throughout the accommodation spaces, service spaces and control stations. One manually operated call point is to be located at each exit. Manually operated call points are to be readily accessible in the corridors of each deck such that no part of the corridor is more than 20 m from a manually operated call point.

2.2.2 Smoke detectors are to be installed in all stairways, corridors and escape routes within accommodation spaces.

2.2.3 Where a fixed fire detection and fire-alarm system is required for the protection of spaces other than those specified in 2.2.2, at least one detector complying with 2.1.3, is to be installed in each such space.

2.2.4 Detectors are to be located for optimum performance. Positions near beams and ventilation ducts or other positions where patterns of air flow could adversely affect performance and positions where impact or physical damage is likely are to be avoided. In general, detectors which are located overhead are to be a minimum distance of 0,5 m away from bulkheads.

2.2.5 The maximum spacing of detectors is to be in accordance with Table 4.2.1. Other spacings based upon test data which demonstrate the characteristics of the detectors may be required or permitted.

Table 4.2.1 Maximum spacing of detectors

Maximum		Maximum	
Maximum floor		Distance apart between centres, in metres	Distance away from bulkheads, in metres
Type of detector	Area per detector, m^2		
Heat	37	9	4,5
Smoke	74	11	5,5

2.2.6 Electrical wiring which forms part of the system is to be so arranged as to avoid galleys, machinery spaces of Category 'A', and other enclosed spaces of high fire-risk except where it is necessary to provide for fire detection or fire-alarm in such spaces or to connect to the appropriate power supply. *See also* Pt 16, Ch 2.

2.3 Design requirements

2.3.1 Smoke detectors required by 2.2.2 are to be certified to operate before the smoke density exceeds 12,5 per cent obscuration per metre, but not until the smoke density exceeds two per cent obscuration per metre. Smoke detectors to be installed in other spaces are to operate within satisfactory sensitivity limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.2 Heat detectors are to be certified to operate before the temperature exceeds 78°C but not until the temperature exceeds 54°C, when the temperature is raised to those limits at a rate less than 1°C per minute. At higher rates of temperature rise, the heat detector is to operate within satisfactory temperature limits having regard to the avoidance of detector insensitivity or oversensitivity.

2.3.3 The permissible temperature of operation of heat detectors may be increased to 30°C above the maximum deckhead temperature in drying rooms and similar spaces of a normal high ambient temperature.

2.4 Requirements for machinery spaces

2.4.1 The arrangements of the fixed fire detection and fire-alarm system in machinery spaces are to comply with the requirements of Pt 16, Ch 1,2.8.

■ *Section 3* Fixed fire-extinguishing systems in machinery spaces

3.1 Gas fire-extinguishing systems

3.1.1 The use of a fire-extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons is not permitted.

3.1.2 New installations that use fire-extinguishing media, which have ozone-depleting properties under the Montreal Protocol, are not permitted.

3.1.3 The necessary pipes for conveying a fire-extinguishing medium into protected spaces are to be provided with control valves which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. The control valves are to be so marked as to indicate clearly the spaces to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the medium to any space. Where pipes pass through accommodation spaces they are to be seamless and the number of pipe joints is to be kept to a minimum and made by welding.

3.1.4 The piping for the distribution of fire-extinguishing medium is to be of adequate size and so arranged, and discharge nozzles so positioned that a uniform distribution of medium is obtained. All pipes are to be arranged to be self draining and where led into refrigerated spaces, the arrangement will be specially considered. A means whereby the individual pipes to all protected spaces can be tested using compressed air is to be provided. Distribution pipes are to extend at least 50 mm beyond the last nozzle.

3.1.5 Steel pipes fitted in spaces where corrosion is likely to occur are to be galvanised, at least internally.

3.1.6 Distribution pipes for carbon dioxide are not to be smaller than 20 mm bore.

3.1.7 Means are to be provided to close all openings which may admit air into, or allow gas to escape from, a protected space.

3.1.8 The volume of starting air receivers, converted to free air volume, is to be added to the gross volume of the machinery space when calculating the necessary quantity of extinguishing medium. Alternatively a discharge pipe from the safety valves may be fitted and led directly to the open air.

3.1.9 Means are to be provided for automatically giving audible and visual warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for a suitable period before the medium is released.

3.1.10 Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided that the air supply is clean and dry.

3.1.11 Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside hazardous spaces.

3.1.12 The means of control of any fixed gas fire-extinguishing system is to be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by a fire in a protected space. At each location there is to be clear instructions relating to the operation of the system having regard to the safety of personnel. Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space, in which personnel normally work or to which they have access, *see also* 3.1.9. The space served is to be identified at the release box.

3.1.13 Automatic release of fire-extinguishing medium is not permitted.

3.1.14 Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected.

3.1.15 Means are to be provided for the crew to safely check the quantity of medium in the containers.

3.1.16 Containers for the storage of fire-extinguishing media and associated pressure components are to be designed and tested to Codes of Practice recognised by Lloyd's Register (hereinafter referred to as 'LR') having regard to their locations and the maximum ambient temperatures expected in service.

3.1.17 The fire-extinguishing medium is to be stored outside a protected space, in a room which is situated in a safe and readily accessible position and effectively ventilated. Any entrance to such a storage room is to preferably be from the open deck and in any case be independent of the protected space. Access doors are to open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form the boundaries between such rooms and adjoining enclosed spaces are to be gastight. Such storage rooms are to be treated as control stations.

3.1.18 In systems where containers discharge into a common manifold, non-return valves are to be provided at the connections of the container discharge pipes to the manifold to allow any container to be disconnected without preventing the use of other containers in the system and to prevent the discharge of extinguishing medium into the container storage room in the event of the system being operated. Manifolds are to be tested by hydraulic pressure to 1,5 times the design pressure. The design pressure is the maximum gauge pressure to which the system may be subjected and is not to be less than the gauge pressure corresponding to the maximum ambient temperature expected in service. The design pressure need not be greater than the maximum setting of the manifold pressure relief valve. After the hydraulic test, manifolds are to be carefully cleaned and dried before the non-return valves are finally fitted.

3.1.19 For craft on unrestricted service, spare parts for the system are to be stored on board. As a minimum these are to consist of:

- 1 actuator;
- 1 flexible hose (cylinder to manifold); and
- the cylinder bursting discs and sealing washers for all cylinders.

3.2 Carbon dioxide systems

3.2.1 Carbon dioxide systems are to comply with 3.1 in addition to the remaining requirements of this sub-Section.

3.2.2 For the purpose of this paragraph the volume of free carbon dioxide is to be calculated at 0,56 m^3/kg.

3.2.3 For machinery spaces:

(a) The quantity of carbon dioxide carried is to be sufficient to give a minimum volume of free gas equal to the larger of:
   - 40 per cent of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40 per cent or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
   - 35 per cent of the gross volume of the largest machinery space protected, including the casing.

(b) The above mentioned percentages may be reduced to 35 per cent and 30 per cent respectively for craft less than 2000 gross tons.

(c) The fixed piping system is to be such that 85 per cent of the gas can be discharged into the space within two minutes.

(d) The distribution arrangements are to be such that approximately 15 per cent of the required quantity of carbon dioxide is led to the bilge areas.

3.2.4 Two separate controls are to be provided for releasing carbon dioxide into a protected space and each is to ensure the activation of the alarm. One control is to be used to discharge the gas from its storage cylinder(s). A second control is to be used for opening the valve of the piping which conveys the gas into the protected space. The two controls are to be located inside a release box clearly identified for the particular space. If the box containing the controls is to be locked, a key to the box is to be in a break-glass type enclosure conspicuously located adjacent to the box. There is to be a dedicated release box for each protected space in which personnel normally work or to which they have access, *see also* 3.1.8. The space served is to be identified at the release box.

3.3 High-expansion foam systems

3.3.1 Any required fixed high-expansion foam system in machinery spaces is to be capable of rapidly discharging through fixed discharge outlets a quantity of foam sufficient to fill the greatest space to be protected at a rate of at least 1 m in depth per minute. The quantity of foam-forming liquid available is to be sufficient to produce a volume of foam equal to five times the volume of the largest space to be protected.

3.3.2 The expansion ratio of the foam is not to exceed 1000 to 1.

3.3.3 Alternative arrangements and discharge rates will be permitted provided that equivalent protection is achieved.

3.3.4 Supply ducts for delivering foam, air intakes to the foam generator and the number of foam producing units are to be such as will provide effective foam production and distribution.

3.3.5 The arrangement of the foam generator delivery ducting is to be such that a fire in the protected space will not affect the foam-generating equipment.

3.3.6 The foam generator, its sources of power supply, foam-forming liquid and means of controlling the system are to be readily accessible and simple to operate and are to be grouped in as few locations as possible at positions not likely to be cut off by fire in the protected space. Such spaces are to be treated as control stations.

3.3.7 Foam concentrates are to be of an approved type.

3.4 Pressure water-spraying systems

3.4.1 Any required fixed pressure water-spraying fire-extinguishing system in machinery spaces is to be provided with spraying nozzles of an approved type.

3.4.2 The number and arrangement of the nozzles is to be such as to ensure an effective average distribution of water of at least five litres per square metre per minute in the spaces to be protected. Where increased application rates are considered necessary, these will be specially considered. Nozzles are to be fitted above bilges, tank tops and other areas over which oil fuel is liable to spread and also above other specific fire hazards in the machinery spaces.

3.4.3 The system may be divided into sections, the distribution valves of which are to be operated from easily accessible positions outside the spaces to be protected and which will not be readily cut off by fire in the protected space.

3.4.4 The system is to be kept charged at the necessary pressure, and the pump supplying the water for the system is to be put automatically into action by a pressure drop in the system.

3.4.5 The pump is to be capable of simultaneously supplying, at the necessary pressure, all sections of the system in any one compartment to be protected. The pump and its controls are to be installed outside the space or spaces to be protected. It is not to be possible for a fire in the space or spaces protected by the water-spraying system to put the system out of action.

3.4.6 The pump may be driven by independent internal combustion type machinery but if it is dependent upon power being supplied from the emergency generator, that generator is to be arranged to start automatically in case of main power failure so that power for the pump required by 3.4.5 is immediately available. When the pump is driven by independent internal combustion machinery it is to be so situated that a fire in the protected space will not affect the air supply to the machinery.

3.4.7 Precautions are to be taken to prevent the nozzles from becoming clogged by impurities in the water or corrosion of the piping, nozzles, valves and pump.

3.5 Arrangements which will be accepted as an alternative to 3.4

3.5.1 The system is to be tested, type approved and installed in accordance with MSC/Circ. 668 as amended by IMO MSC/Circ. 728.

3.6 Other systems

3.6.1 Other fixed fire-extinguishing systems will be specially considered.

3.6.2 The use of steam as a fire-extinguishing medium in fixed fire-extinguishing systems is not permitted.

■ *Section 4* Fireman's outfits

4.1 Components

4.1.1 A fireman's outfit is to consist of:

(a) Personal equipment comprising:
   - (i) Protective clothing of material to protect the skin from the heat radiating from the fire and from burns and scalding by steam. The outer surface is to be water-resistant.
   - (ii) Boots and gloves of rubber or other electrically non-conducting material.
   - (iii) A rigid helmet providing effective protection against impact.
   - (iv) An electric safety lamp (hand lantern) of an approved type with a minimum burning period of three hours.
   - (v) An axe with an insulated handle.

(b) A self contained breathing apparatus of an approved type. The volume of air contained in the cylinders of which is to be at least 1200 litres or other self contained breathing apparatus which is to be capable of functioning for a period of at least 30 minutes. Spare bottles are to be provided which are to be maintained fully charged except where facilities for re-charging the bottles are available on board. At least two spare charges for each breathing apparatus are to be provided, and all air cylinders for breathing apparatus are to be interchangeable.

4.1.2 For each breathing apparatus a fireproof life-line of sufficient length and strength is to be provided capable of being attached by means of a snaphook to the harness of the apparatus or to a separate belt in order to prevent the breathing apparatus becoming detached when the life-line is operated.

■ *Section 5* Fire-control plans

5.1 Description of plans

5.1.1 General arrangement plans are to be permanently exhibited for the guidance of the ship's officers, using graphical symbols in accordance with IMO Resolution A.654(16), which show clearly for each deck the control stations, the various fire sections enclosed by steel or 'A' and 'B' Class divisions, together with particulars of:

- the fire detection and fire-alarm system;
- any sprinkler installation;
- the fire-extinguishing appliances;
- the means of access to different compartments, decks, etc.;
- the position of the fireman's outfits;
- the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating fans serving each section; and

- the location and arrangement of the emergency stop(s) for pumps, and for remote closing the valves on the pipes from tanks, for oil fuel, lubricating oil and other flammable oils.

5.1.2 Alternatively, the details required by 5.1.1 may be set out in a booklet, a copy of which is to be supplied to each officer, and one copy is at all times to be available on board in an accessible position.

5.1.3 The plans and booklets are to be kept up to date, any alterations being recorded thereon as soon as practicable. Description in such plans and booklets is to be in the official language of the flag state. If the language is neither English nor French, a translation into one of those languages is to be included. In addition, instructions concerning the maintenance and operation of all the equipment and installations on board for the fighting and containment of fire are to be kept under one cover, readily available in an accessible position.

5.1.4 A duplicate set of fire-control plans or a booklet containing such plans is to be permanently stored in a prominently marked weathertight enclosure outside the deckhouse for the assistance of shoreside fire-fighting personnel.

■ *Section 6* Fire-extinguishers (portable and non-portable)

6.1 Approved types

6.1.1 All fire-extinguishers are to be of approved types and designs.

6.2 Extinguishing medium

6.2.1 The extinguishing media employed are to be suitable for extinguishing fires in the compartments in which they are intended to be used.

6.2.2 The extinguishers required for use in the machinery spaces using oil as fuel are to be of a type suitable for extinguishing oil fires.

6.2.3 Fire-extinguishers containing an extinguishing medium which, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons, are not permitted.

6.3 Capacity

6.3.1 The capacity of required portable fluid extinguishers is to be not more than 13,5 litres but not less than nine litres. Other extinguishers are to be at least as portable as the 13,5 litre fluid extinguishers and are to have a fire-extinguishing capability at least equivalent to a 9,0 litre fluid extinguisher.

6.3.2 The following capacities may be taken as equivalents:
- 9 litre fluid extinguisher;
- 4,5 kg dry powder;
- 5 kg carbon dioxide.

6.4 Spare charges

6.4.1 A spare charge is to be provided for each required portable fire-extinguisher which can be readily re-charged on board. If this cannot be done, duplicate extinguishers are to be provided.

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Guidance Notes for the Classification of Special Service Craft

Calculation Procedures for Composite Construction

July 2012

CALCULATION PROCEDURES FOR COMPOSITE CONSTRUCTION

Contents

Procedures Manual

Introduction

■ Application of procedures

To clarify the procedures contained in the *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft) a series of typical calculation procedures are contained in these 'Guidance Notes'. The procedures describe the fundamental principles contained in Part 8 of the Rules for Special Service Craft and the associated computer software.

The procedures contained in these Guidance Notes are for:
(a) Design of single skin hull laminates.
(b) Design of sandwich panel laminates.
(c) Design of typical stiffening members.

■ Alternative procedures

The procedures describe the Rule method of calculating the various stresses in laminates. Where alternative theoretical methods are to be adopted they are to be in addition to the Rule calculation procedures and the designer is to submit full details of their assumptions and calculation procedures such that the submitted calculations may be validated.

■ Symbols and definitions

All symbols and definitions are as indicated in Pt 8, Ch 3 of the Rules for Special Service Craft.

■ *Section 1* General

1.1 This Section outlines the Rule approach to the design of structural members to be built in FRP and provides example calculations.

1.2 The procedures contained in these Guidance Notes are for:

(a) Design of single skin hull laminates.
(b) Design of sandwich panel laminates.
(c) Design of typical stiffening members.

■ *Section 2* Structural analysis

2.1 The Rules for Special Service Craft provide scantling requirements for a basic structural configuration for both mono and multi-hull craft with multi-deck or single deck hulls which include a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of cargo hatch openings. The Rules for Special Service Craft provide for both longitudinal and transverse framing systems. Alternative types of framing systems will be specially considered on the basis of the Rules for Special Service Craft.

2.2 Every effort has been taken to make the Rules for Special Service Craft scantling formulae as transparent as possible, and to achieve this objective the following approach has been adopted:

- lay down requirements,
- specify modelling considerations,
- indicate limit states,
- state constraints in an explicit manner.

2.3 This approach will enable the designers and Builders to decide for themselves the suitability of the Rules for Special Service Craft for their project. Further and perhaps more importantly changes may be easily made to the requirements based upon experience gained, discussions with interested parties and as development progresses. This is similar to the current Rule development process which is continually updating and ‘tailoring’ Rule requirements.

■ *Section 3* Fibre composites

3.1 Part 8 of the Rules for Special Service Crafts apply to craft constructed of fibre reinforced plastics using hand lay-up, mechanical deposition, contact moulding techniques or vacuum assisted techniques. Construction may be either single-skin or sandwich construction, or a combination of both. Where moulding techniques and methods of construction differing from those assumed to be used within the Rules for Special Service Craft are proposed, details are required to be submitted for consideration.

3.2 For the purposes of the Rules for Special Service Craft a ‘plastic’ is regarded as an organic substance which may be thermosetting or thermoplastic and which, in its finished state, may contain reinforcements or additives. The quantities of such additives are strictly limited by the Rules for Special Service Craft.

3.3 The resins used in production are to be of a type which have been approved by Lloyd’s Register (hereinafter referred to as LR) for marine construction purposes. Samples of the resin batches being used in the construction may require to be taken for limited quality control examinations.

3.4 All fibre reinforcements are to be of a type approved by LR. The other materials used in the construction of the craft are also to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials), of the Rules for Special Service Craft, with particular reference to Chapter 14 for plastics materials.

■ *Section 4* Fibre reinforced composite construction

4.1 The properties of composite sections and laminates are to be determined from the results of test data. The mechanical properties to be used for scantling calculation purposes are to be 90 per cent of the mean first ply/resin cracking failure values determined from accepted mechanical tests. All test pieces are to be representative of the product to be manufactured. This is particularly important since the material of construction is ‘manufactured’ on site, at the same time as the product.

4.2 The mechanical properties of the materials are also to be estimated from the appropriate procedures and formulae contained within the Rules for Special Service Craft. The acceptable design values for glass reinforced polyester resin laminates are not to be greater than those contained with the Rules for Special Service Craft unless agreed otherwise by LR. Additional information on the application of the various formulae is given in these Guidance Notes.

4.3 The various formulae referred to above require that sufficient input data be available which relates to each of the proposed materials. Where it is proposed to use design values greater than the nominal value indicated in the Rules for Special Service Craft the designers and/or Builders should agree the values for use in the scantling analysis with LR at the design stage and prior to the submission of plans and data for appraisal.

4.4 Strength calculations for all advanced fibre composites are to be based on the Rules values and the results of testing of truly representative sections of the proposed design. The sections are to be manufactured under typical production conditions using the same materials, fibre contents, methods of lay-up and time delays. Mechanical testing is, in general, to be based upon the requirements specified in Chapter 14 of the Rules for Materials.

4.5 A through ply analysis is required to be conducted for both plate and stiffener elements and the resultant stresses compared with the allowable stress limits for the particular element. Example procedures are described in these Guidance Notes.

■ *Section 5* Direct calculations

5.1 Direct calculations may be specifically required by the Rules for Special Service Craft. They may be required for craft having novel design features, or may be submitted in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers or Builders and make recommendations with regard to the suitability of any required model tests. Where model testing is undertaken to complement direct calculations details would normally be required to be submitted indicating the schedule of tests, details of test equipment, input data, analysis and calibration procedures together with tabulated and plotted output.

5.2 All direct calculations are to be submitted for examination. Where calculation procedures other than those available within the Rules for Special Service Craft are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods,
- assumptions and references,
- loading data,
- structural modelling,
- design criteria.

5.3 LR will consider the use of Builder's and/or designer's programs for direct calculations in the following cases:

- where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted,
- where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

5.4 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the Builder and/or designer to demonstrate their suitability and equivalence to the Rule requirements. Alternative arrangements, which are in accordance with the requirements of a National Authority, may be accepted as equivalent to the requirements of the Rules for Special Service Craft.

5.5 These Guidance Notes are published to enable designers/Builders to carry out the Rule calculations without using the Rules for Special Service Craft software.

Design of Single Skin Hull Laminates

Section

Section 1
Calculation procedure

1.1 The stress in individual plies of a laminate is calculated in accordance with Pt 8, Ch 3,1.12 of the Rules for Special Service Craft, based on bending moment (*see* 1.9) and the laminate stiffness of a 1 cm wide elemental strip of material.

1.2 Considering the model shown in Figs. 2.1.1 and 2.1.2 of a typical single skin hull laminate. Assume a pressure of 33 kN/m^2 and that there is no significant panel curvature.

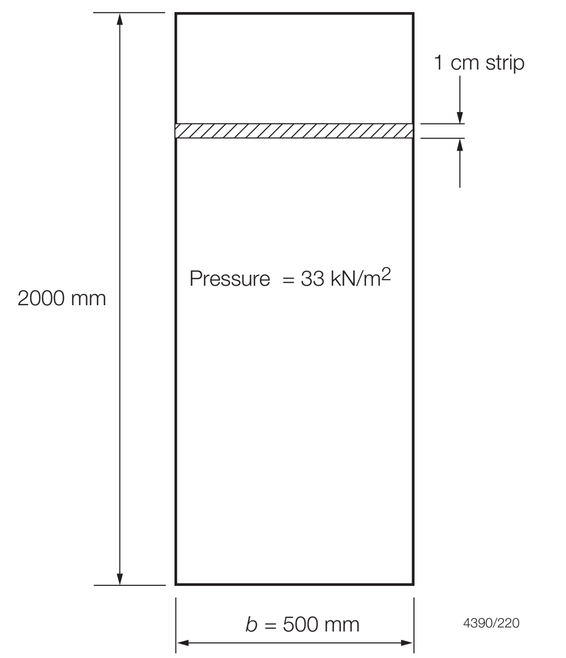

Fig. 2.1.1 Single skin example model

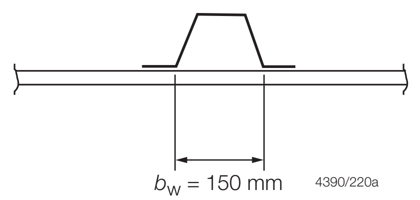

Fig. 2.1.2 'Top-hat' stiffener used in model

1.3 In this example the maximum bending moment is determined from Pt 8, Ch 3,1.9 of the Rules for Special Service Craft and occurs under the web at the base of the stiffener. It should be noted that no reduction in the bending moment, M_b, due to aspect ratio effect is given since the panel aspect ratio, i.e. panel length/panel breadth is greater than 2. *See* Pt 8, Ch 3,1.10.1 of the Rules for Special Service Craft.

$$\gamma = \frac{b_w}{b} = \frac{150}{500} = 0{,}3$$

$$k = \frac{\gamma^3 + 1}{\gamma + 1} = 0{,}79$$

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5} \text{ Nm}$$

$$= \frac{0{,}79}{12} \times 33 \times 500^2 \times 10^{-5}$$

$$= 5{,}43 \text{ Nm.}$$

1.4 The laminate section modulus calculation is shown in Table 2.1.1 at the end of this Section. From Fig. 2.1.3 it will be noted that there will be positions where tension and compression considerations will apply. Such calculations are ideally suited to computer based investigation.

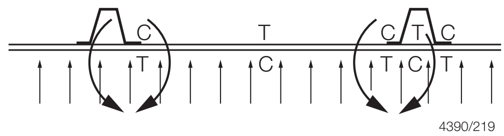

Fig. 2.1.3
Regions of tension (T) and compression (C) in example model

1.5 In order to apply a more detailed investigation it is necessary to establish the position of the neutral axis. However, in relatively balanced laminates this may be assumed to be at mid-depth. The procedure is simply to carry out the calculations assuming compressive properties on one face and tensile properties on the other face. Subsequently, the properties should be reversed and the layer stress calculations repeated. The calculated values should then be compared with the appropriate ultimate properties, i.e., dependent upon whether tension or compression considerations apply.

1.6 In the example the moments were evaluated about the base, which was taken to be the outer (wet) surface. The stiffness, EI, per 1 cm width, about the neutral axis, is determined using the parallel axis theorem:
In general:

$$I_{na} = I_{xx} - Ay^2$$
$$EI_{sect} = \Sigma EI_{base} - (\Sigma Et) \times 10 \times y^2$$

where

y = distance of neutral axis above the base (mm).

Table 2.1.1 Tabulation of single skin laminate calculations

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Lever @ base, x (mm)	E (N/mm^2)	$E.t$	$E.t.x$	I @ base	EI @ base
Dry, *see* Note	1	CSM	0,33	600	1,250	10,149	7200	9000	91341	1289,2	9281917
	2	CSM	0,33	600	1,250	8,899	7200	9000	80091	991,5	7139017
	3	CSM	0,33	600	1,250	7,649	7200	9000	68841	733,0	5277367
	4	CSM	0,33	600	1,250	6,399	7200	9000	57591	513,5	3696967
	5	WR	0,5	600	0,734	5,407	14000	10276	55562	214,9	3008869
	6	CSM	0,33	600	1,250	4,415	6950	8688	38355	245,3	1704699
	7	CSM	0,33	600	1,250	3,165	6950	8688	27496	126,8	881558
	8	WR	0,5	600	0,734	2,173	14500	10643	23127	35,0	507333
	9	CSM	0,33	600	1,250	1,181	6950	8688	10260	19,1	132482
Wet (*see* Note)	10	CSM	0,286	225	0,556	0,278	6290	3497	972	0,6	3604
TOTALS					10,774			86479	453637		31633812

NOTE
'Dry' indicates the inner surface of the hull and 'wet' the outside of the shell laminate.

Position of neutral axis above base = $\dfrac{453637}{86479}$ = 5,246 mm

Tensile modulus of section = $\dfrac{86479}{10,774}$ = 8027 N/mm^2

Stiffness *EI* about neutral axis = 783,8 N cm^4/mm^2 (based on 1 cm wide strip)

1.7 A factor of 10 (width in mm) is introduced to correct the value of area used in the parallel axis theorem, since a 1 cm wide strip of material is considered in the calculations.
From the tabulation:

EI_{sect} = 31633812 – (86479 x 10 x 5,246^2)
= 7837614 Nmm^4/mm^2
= 783,8 Ncm^4/mm^2.

1.8 From Pt 8, Ch 3,1.12 of the Rules for Special Service Craft the individual layer stresses (tensile consideration) are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma\,(E_i\, I_i)} \times 10^{-1} \quad \text{N/mm}^2$$

1.9 More generally, the calculation of the stresses in individual layers becomes:

$$\sigma_{ti} = \frac{5{,}43}{783{,}8} \times E_i\, y_i \times 10^{-1} \quad \text{N/mm}^2$$
$$= 693 \times 10^{-6} \times E_i\, y_i \quad \text{N/mm}^2$$

where

E_i = E_{ti} or E_{ci} for the ply relative to its position above or below the neutral axis
y_i = distance from the neutral axis to the outer extremity of an individual ply, *i*, in mm.

1.10 Consider the following typical arrangement and the associated stresses for a single shell panel outside of the slamming zone:

Consider the outer (wet) surface:
Consider the 225g/m^2 chopped strand mat reinforcement in tension:

σ_{ti} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 6290 x 5,246
= 22,9 N/mm^2.

From Pt 8, Ch 3, Table 3.1.1 of the Rules for Special Service Craft.
$\sigma_{ult\ tension}$ = 82,2 N/mm^2 for CSM at G_c =0,286
Hence, stress fraction = 22,9/82,2 = 0,278.

1.11 From Table 7.3.1 in Pt 8, Ch 7 of the Rules for Special Service Craft, the limiting tensile stress fraction is 0,33 for the side shell outside of the slamming zone. Hence, the calculated stress fraction is lower than the limiting stress factor and is therefore acceptable.

1.12 Similarly, consider the 600g/m^2 woven roving reinforcement in tension:

σ_{ti} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 14500 x (5,246–0,556–1,25)
= 34,6 N/mm^2

$\sigma_{ult\ tension}$ = 190 N/mm^2 for woven roving at G_c = 0,5
Stress fraction = 34,6/190 = 0,182
Hence acceptable.

1.13 Consider the inner (dry) surface:
The 600 g/m^2 chopped strand mat reinforcements at the inner surface in compression:

σ_{ci} = 693 x 10^{-6} x $E_i\, y_i$
= 693 x 10^{-6} x 7200 x (10,774–5,246)
= 27,6 N/mm^2

$\sigma_{ult\ comp}$ = 122 N/mm^2 for CSM at G_c = 0,33
Stress fraction = 27,6/122 = 0,226
Hence acceptable.

■ *Section 2* **Concluding remarks**

2.1 From the example, the highest stress factor occurs in the outer 225 g/m^2 chopped strand mat reinforcement (in tension) but this is significantly lower than the limiting stress fraction required by the Rules. The bending moment at the centre of the panel is smaller than that at the boundary and consequently, the stress factor will be correspondingly reduced. The design may be optimised by sequentially removing plies, changing reinforcement weights and/or by providing receiving strips under the base of the 'top-hat' stiffeners.

2.2 For the design of side shell laminates there are no shear and deflection criteria to be fulfilled. In this example a significant reserve exists between the actual and the ultimate stresses.

2.3 It is of paramount importance that the strain compatibility of the component materials is carefully considered.

2.4 Consider typical values of apparent strain, ε_a, at failure for the following materials in laminate form:

	Tension	Compression
'E' glass	1,3%	1,05%
Carbon fibre	0,9%	0,55%
Aramid fibre	1,3%	0,60%

2.5 The actual strain permissible is controlled by the material with the lowest apparent strain. The level of strain depends upon whether the reinforcements are in tension or compression and depends on their relative positions within the laminate. Consequently if, for example, a carbon fibre reinforcement is used in the outer plies of laminate then the strain must be constrained to a maximum of 0,33 x 0,9 per cent, i.e., 0,297 per cent. Therefore, the corresponding allowable stress in the other reinforcements must be related to the strain in the reinforcement relative to its position away from the neutral axis and that of the carbon fibre reinforcement, e.g.:

$$\varepsilon_{limitCSM} = \frac{\varepsilon_{allowable\ carbon} \times y_{CSM}}{y_{carbon}}$$

2.6 Where aramid reinforcements are being used, special consideration must be given to the compressive properties. For comparison purposes aramid reinforcements, at a fibre content of 0,45 (by weight), typically have the following properties:

	Tension	Compression
Ultimate strength (N/mm^2)	300	100
Elastic modulus (N/mm^2)	21000	17000

2.7 The radical reduction in ultimate compressive strength may prove to be unacceptable on the inside at the panel boundaries or on the outside at the panel centre. Designs which feature aramid fibres in the outer plies, in an attempt to make use of the superior impact properties, must be checked at the panel centre for compression in the individual layers. This also applies to hybrid reinforcements containing aramid fibres. These reinforcements have one off properties of higher than one of the constituent fibres however, in service the individual allowable strains for each fibre reinforcement should not be exceeded.

Section

Section 1
Calculation procedure

1.1 Consider the model of a side shell sandwich panel having dimensions 700 mm x 2000 mm shown in Fig. 3.1.1. Assume a design pressure of 50 kN/m^2 and a panel of negligible curvature.

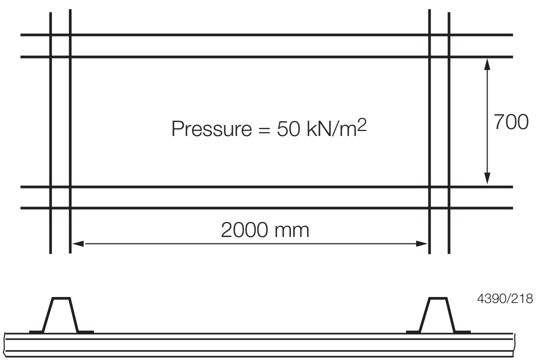

Fig. 3.1.1 Sandwich panel laminate example model

1.2 The panel is to be designed in accordance with the requirements of Pt 8, Ch 3 of the Rules for Special Service Craft. Firstly it is necessary to estimate the core thickness using Pt 8, Ch 3,1.13.2 of the Rules for Special Service Craft assuming a nominal value of tensile modulus of 11000 N/mm^2 for sandwich panel facings:

$$t_s = \phi\, k_s\, b \sqrt[3]{\frac{p}{E_{tpS}}} \quad \text{mm}$$

$$= 0{,}144 \times 700 \times \sqrt[3]{\frac{50}{11000}}$$

$$= 16{,}7 \text{ mm}$$

Hence, select 20 mm core as a typically available size.

1.3 From Pt 8, Ch 3,1.13.9 of the Rules for Special Service Craft the maximum core shear at the mid-point along the edge of the sandwich panel is given by:

$$\tau_c = \frac{p\, b\, k_S}{2t_c} \times 10^{-3} \quad \text{N/mm}^2$$

$$= \frac{50 \times 700 \times 1}{2 \times 20} \times 10^{-3}$$

$$= 0{,}875 \text{ N/mm}^2$$

1.4 The panel aspect ratio correction factor is given in Pt 8, Ch 3,1.13.9 of the Rules for Special Service Craft. A_R = 2000/700 = 2,86, hence k_S = 1.
No correction factor applied since $A_R > 2$.

1.5 To achieve an allowable shear stress fraction of 0,30, *see* Pt 8, Ch 7,3.5 of the Rules for Special Service Craft, this design would require the selection of 200 kg/m^3 foam core. Clearly being unacceptable the conclusion is to adopt a 50 mm thick core to reduce the core shear stress. The stress varies inversely with core thickness:

$$\tau_{50} = \tau_{20} \times \frac{20}{50} = 0{,}35 \quad \text{N/mm}^2.$$

1.6 To achieve the required allowable shear stress fraction the foam core must have a core shear strength of 0,35/0,30 = 1,17 N/mm^2. This may be achieved using a 100 kg/m^3 foam core using 90 per cent of the manufacturer's quoted value.

1.7 However, there are numerous solutions to achieve an acceptable arrangement. The options include:
(a) Repositioning the stiffeners to reduce panel sizes.
(b) Inclusion of shear ties in accordance with Pt 8, Ch 3,1.13.10 of the Rules for Special Service Craft.
(c) Accept the higher density core solution.

1.8 From Pt 8, Ch 3,1.13.3 of the Rules for Special Service Craft the skin thicknesses may be re-calculated allowing for the change in core thickness:

$$t_S = \phi_2 \frac{p\, b^3}{E_{tps}\, t_c^2} \times 10^{-3} \quad \text{mm}$$

$$t_{inner} = 0{,}446 \times \frac{50}{11000} \times \frac{700^3}{50^2} \times 10^{-3} = 0{,}28 \text{ mm}$$

$$t_{outer} = 0{,}594 \times \frac{50}{11000} \times \frac{700^3}{50^2} \times 10^{-3} = 0{,}37 \text{ mm}$$

Clearly, the increase in core thickness gives a substantial increase in panel stiffness. Consequently the skin thicknesses default to the minimum requirement quoted in Pt 8, Ch 3,3.5.5 of the Rules for Special Service Craft. The minimum side shell sandwich skin thicknesses are:

Outer 4 mm
Inner 3 mm.

1.9 The minimum skin thicknesses relate to an assumed fibre content, f_c, of 0,5. Where the fibre content by weight is less than 0,5 the required minimum thickness are to be determined from Pt 8, Ch 3,2.4.2 of the Rules for Special Service Craft.

1.10 In order to comply with the Rules for Special Service Craft, chopped strand mat reinforcements are required against the core. The initial proposal to meet the requirement, features such CSM reinforcements together with a CSM against the gel coat surface.

1.11 The proposed sandwich skin laminate schedule for the outer skin is:

1 x 450 g/m^2 CSM @ G_c = 0,286	=	1,112 mm
3 x 600 g/m^2 WR @ G_c = 0,5	=	2,202 mm
1 x 300 g/m^2 CSM @ G_c = 0,33	=	0,625 mm
Total outer skin thickness	=	3,94 mm
Total reinforcement weight	=	2550 g/m^2

1.12 By transforming the relationship given in Pt 8, Ch 3,1.6.1 of the Rules for Special Service Craft the equivalent fibre content by weight, f_c, is 0,42.
The adjusted minimum skin thickness for the outer skin is:

$$t_{outer} = t_{0,5}\,(1{,}65 - 1{,}3 f_c)$$
$$= 4 \times (1{,}65 - 1{,}3 \times 0{,}42)$$
$$t_{outer} = 4{,}42 \text{ mm.}$$

1.13 The proposed outer skin is deficient by 4,42 – 3,94 = 0,48 mm. Hence one additional woven roving reinforcement may be added to achieve the minimum requirement. The actual thickness of outer skin is 4,67 mm.

1.14 The proposed sandwich skin laminate schedule for the inner skin is:

1 x 300 g/m^2 CSM @ G_c = 0,33	=	0,625 mm
4 x 600 g/m^2 WR @ G_c = 0,5	=	2,936 mm
Total inner skin thickness	=	3,56 mm
Total reinforcement weight	=	2700 g/m^2

The equivalent overall fibre content of the inner skin is 0,473.
The adjusted minimum skin thickness for the inner skin is:

$$t_{inner} = t_{0,5}\,(1{,}65 - 1{,}3 f_c)$$
$$= 3 \times (1{,}65 - 1{,}3 \times 0{,}473)$$
$$t_{inner} = 3{,}1 \text{ mm.}$$

1.15 The proposed arrangement which meets both core shear and minimum sandwich skin requirements is given in Table 3.1.1.

Table 3.1.1 Tabulation of sandwich panel calculations

	Ref No.	Description	G_c	Weight (g/m^2)	t (mm)	Lever @ base, x (mm)	E (N/mm^2)	$E.t$	$E.t.x$	I @ base	EI @ base
Inner skin	1	WR	0,5	600	0,734	57,87	14000	10276	594641	24579	344105690
	2	WR	0,5	600	0,734	57,13	14000	10276	587099	23959	335431718
	3	WR	0,5	600	0,734	56,40	14000	10276	579556	23348	326868472
	4	WR	0,5	600	0,734	55,67	14000	10276	572014	22744	318415951
	5	CSM	0,33	300	0,625	54,99	7200	4500	247435	18896	136054699
Core	6	100 kg/m^3	–	–	50,000	29,67	83,7	4185	124182	544410	45567128
	7	CSM	0,33	300	0,625	4,36	6950	4344	18941	119	827333
	8	WR	0,5	600	0,734	3,68	14500	10643	39177	100	1446879
	9	WR	0,5	600	0,734	2,95	14500	10643	31365	64	929103
	10	WR	0,5	600	0,734	2,21	14500	10643	23553	36	526005
Outer skin	11	WR	0,5	600	0,734	1,48	14500	10643	15741	16	237588
	12	CSM	0,286	450	1,112	0,56	6290	6994	3889	5	28830
TOTALS					58,23			103699	2837592		1510439396

Inner skin in compression/outer skin in tension.

Position of neutral axis above base = $\dfrac{2837592}{103699} = 27{,}36$ mm

Tensile modulus of elasticity of section = $\dfrac{103699 - 4185}{58{,}234 - 50} = \dfrac{99514}{8{,}234} = 12086$ N/mm^2

Stiffness EI about neutral axis = 73397 N cm^4/mm^2 per 1 cm wide strip

■ *Section 2*

Deflection of sandwich panel

2.1 Consider the revised model shown in Fig. 3.2.1:

E_{ms} = 12086 N/mm^2 from Table 3.1.1
b = breadth in direction of bending = 700 mm
G = shear modulus for 100 kg/m^3 core
= 36 N/mm^2 being 90 per cent of the manufacturer's quoted value
t_s = mean skin thickness
(3,56 + 4,67)/2 = 4,11 mm
$(1 - v_f^2)$ = unity (approximately)

Calculation of deflection in accordance with Pt 8, Ch 3,1.13.15 of the Rules for Special Service Craft

$$\delta = \frac{p\,b^2}{8t_c}\left(\frac{b^2}{24E_{ms}\,t_s\,t_c} + \frac{1}{G}\right) \text{x } 10^{-3} \text{ mm}$$

$$= \frac{50 \text{ x } 700^2}{8 \text{ x } 50}\left(\frac{700^2}{24 \text{ x } 12086 \text{ x } 4{,}11 \text{ x } 50} + \frac{1}{36}\right) \text{x } 10^{-3} \text{ mm}$$

= 61,25 x (0,00822 + 0,0278)
= 2,2 mm total deflection.

2.2 The total deflection comprises 23 per cent due to bending and 77 per cent due to shear.
The deflection criterion is given in Table 7.2.1 in Pt 8, Ch 7 of the Rules for Special Service Craft.

$$\delta_{RULE} < \frac{b}{100} \quad \text{where} \quad \frac{b}{100} = 7 \text{ mm}$$

Hence the 2,2 mm total deflection is acceptable.

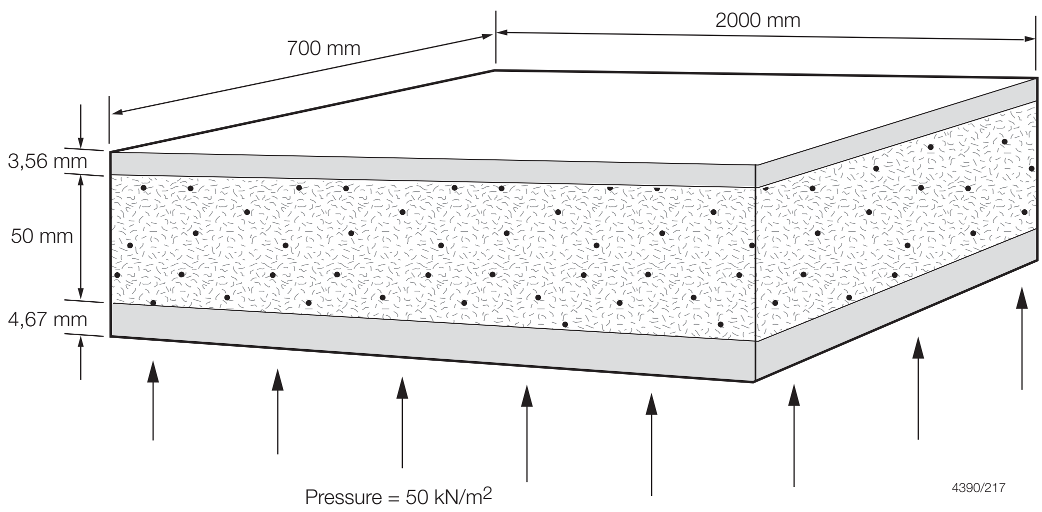

Fig. 3.2.1 Sandwich panel example model

Section 3
Bending moment applied

3.1 The bending moment to be applied at 1 cm width of the sandwich panel is given by Pt 8, Ch 3,1.9 of the Rules for Special Service Craft. In this example it is evident that the maximum bending moment and hence maximum stress occurs under the base of the stiffener. Due to the high aspect ratio no correction factor needs to be applied to modify the applied bending moment.

$$\gamma = \frac{b_w}{b} = \frac{150}{700} = 0{,}2143$$

$$k = \frac{\gamma^3 + 1}{\gamma + 1} = 0{,}8316$$

$$M_b = \frac{k\,p\,b^2}{12} \times 10^{-5}\ \text{Nm}$$

$$= \frac{0{,}8316}{12} \times 50 \times 700^2 \times 10^{-5}$$

$$= 17\ \text{Nm.}$$

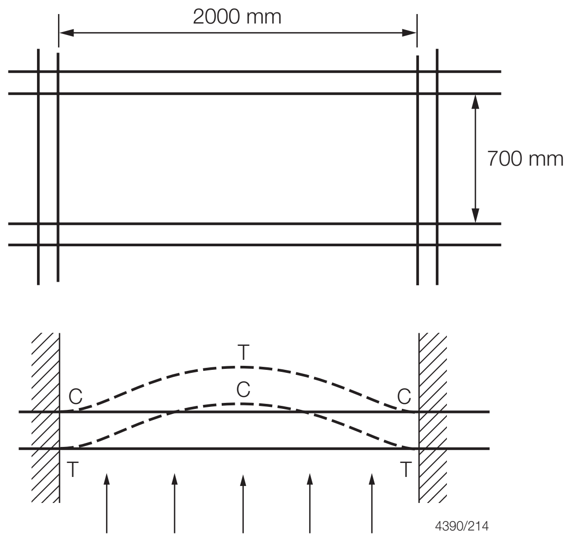

Fig. 3.4.1
Regions of tension (T) and compression (C) in example model

Section 4
Stresses in facings

4.1 Consider the revised model, *see* Fig 3.4.2, with 50 mm thick and 100 kg/m^3 density core having the proposed side shell sandwich skins which comply with the Rules for Special Service Craft minimum requirements. As indicated in Fig. 3.4.1 there will be positions where tension and compression considerations will apply. The relevant elastic modulus has been applied to the element dependent upon its relative position in the sandwich. The proposed schedule together with the tabular calculations are given in Table 3.1.1. Such calculations are ideally suited to computer based investigation.

4.2 The stiffness, EI, per 1 cm width is determined using the parallel axis theorem:
In general,

$I_{na} = I_{xx} - Ay^2$
$EI_{sect} = \Sigma EI_{base} - (\Sigma Et) \times 10 \times y^2$

where
y = distance of neutral axis above base (mm).

4.3 It should be noted that the factor 10 (width in mm) is introduced to correct the value of area used in the parallel axis theorem, since a 1 cm wide strip of material is considered in the calculations.

From the tabulated calculations the overall stiffness of the section is calculated:

$EI_{sect} = 1510439396 - (103699 \times 10 \times 27{,}36^2)$
$= 1510439396 - 776259189\ \ \text{Nmm}^4/\text{mm}^2$
$= 734200000\ \ \text{Nmm}^4/\text{mm}^2$
$= 73{,}4 \times 10^3\ \ \text{Ncm}^4/\text{mm}^2.$

4.4 From Pt 8, Ch 3,1.13.7 of the Rules for Special Service Craft the individual layer stresses are determined from:

$$\sigma_{ti} = \frac{E_{ti}\,y_i\,M}{\Sigma\,(E_i\,I_i)} \times 10^{-1}\ \ \text{N/mm}^2$$

The calculation of the tensile stress in the individual layers becomes:

$$\sigma_{ti} = \frac{17{,}0}{73{,}4 \times 10^3} \times E_{ti}\,y_i \times 10^{-1}\ \ \text{N/mm}^2$$

$$\sigma_{ti} = 23{,}2 \times 10^{-6} \times E_i\,y_i\ \ \text{N/mm}^2$$

where
E_i = modulus of elasticity of layer (N/mm^2)
y_i = distance of layer from the neutral axis (mm).

4.5 Consider the model as shown in Fig. 3.4.1.

4.5.1 Consider wet surface in tension at the panel boundary:

(a) Consider the CSM reinforcement in the outer ply (450 g/m^2 and G_c = 0,286)

σ_{CSMult} = 82,2 N/mm^2
E_t = 6290 N/mm^2
y_i = 27,36 mm
σ_{CSM} = $23{,}2 \times 10^{-6}\,E_t\,y_i$ N/mm^2
= $23{,}2 \times 10^{-6} \times 6290 \times 27{,}36$ N/mm^2
= 3,99 N/mm^2

Stress factor = 3,99/82,2 = 0,05 < 0,33 hence accept.

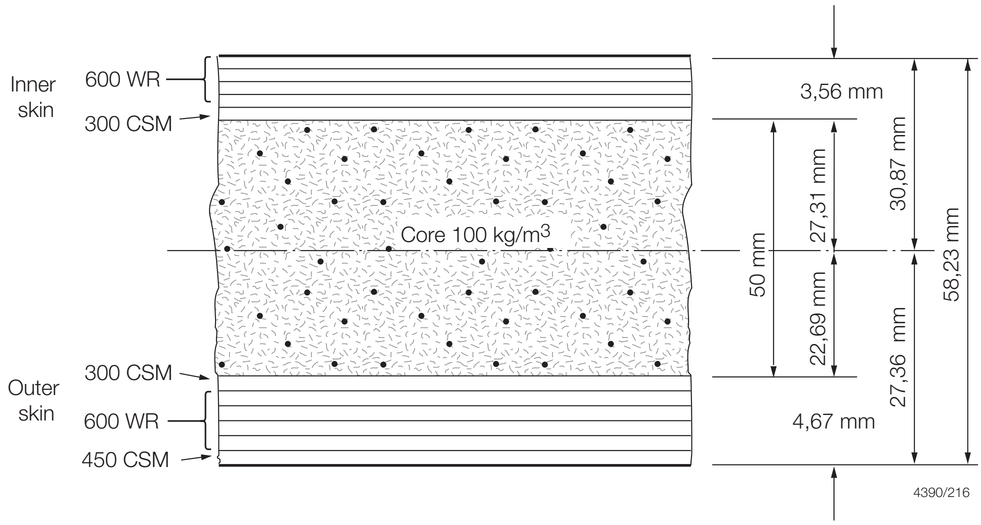

Fig. 3.4.2 Sandwich skin laminate details

(b) Consider the WR reinforcement in the in outer plies (600 g/m^2 and $G_c = 0{,}5$)

σ_{WRult} = 190 N/mm^2
E_t = 14500 N/mm^2
y_i = 27,36 – 1,112 = 26,25 mm
σ_{WR} = $23{,}2 \times 10^{-6}\, E_t\, y_i$ N/mm^2
= $23{,}2 \times 10^{-6} \times 14500 \times 26{,}25$ N/mm^2
= 8,83 N/mm^2

Stress factor = 8,83/190 = 0,046 < 0,33 hence accept.

4.5.2 Consider inner surface in compression at the panel boundary:

(a) Consider top WR reinforcement in compression (600 g/m^2 and $G_c = 0{,}5$)

σ_{WRult} = 147 N/mm^2
E_c = 14000 N/mm^2
y_i = 58,23 – 27,36 = 30,87 mm
σ_{WR} = $23{,}2 \times 10^{-6}\, E_c\, y_i$ N/mm^2
= $23{,}2 \times 10^{-6} \times 14000 \times 30{,}87$ N/mm^2
= 10,03 N/mm^2

Stress factor = 10,03/147 = 0,068 < 0,33 hence accept.

(b) Consider CSM reinforcement in compression (300 g/m^2 and $G_c = 0{,}33$)

σ_{CSMult} = 122 N/mm^2
E_c = 7200 N/mm^2
y_i = 30,87 – (4 x 0,734) = 27,93 mm
σ_{CSM} = $23{,}2 \times 10^{-6}\, E_c\, y_i$ N/mm^2
= $23{,}2 \times 10^{-6} \times 7200 \times 27{,}93$ N/mm^2
= 4,67 N/mm^2

Stress fraction = 4,67/122 = 0,038 < 0,33 hence accept.

4.6 Stress fractions in this example are considerably lower than those required by the Rules for Special Service Craft and it is evident that the design is controlled by and core shear considerations and minimum skin thickness requirements.

4.7 As indicated in Chapter 2, Sections 2.4 to 2.7 of these Guidance Notes for Single Skin Laminates, consideration must be given to the strain compatibility of the reinforcements incorporated in the sandwich skins.

Section

■ *Section 1* Calculation procedure

1.1 Assume a design pressure of 70 kN/m^2 applied to a fully fixed bottom longitudinal located outside of the slamming zone as shown in Fig. 4.1.1.

1.2 The bending moment is determined from Pt 8, Ch 3,1.14.1 of the Rules for Special Service Craft. For a fully fixed stiffener the maximum bending moment coefficient from Table 3.1.5(a) in Pt 8, Ch 3 of the Rules for Special Service Craft is 1/12.

1.3 Hence, maximum bending moment, M_s, is given by:

$$M_s = \frac{s\, l_e^2\, p}{12} \quad \text{Nm}$$

$$M_s = \frac{500 \times l^2 \times 70}{12} \quad \text{Nm}$$

$$M_s = 2917 \quad \text{Nm}$$

Assumed shell laminate:

5 x 800/300 combination mats

G_c = 0,5 (WR in combination mat)
t_{WR} = 0,979 mm
E_t = 14500 N/mm^2

G_c = 0,33 (CSM in combination mat)
t_{CSM} = 0,625 mm
E_t = 6950 N/mm^2

1 x 450 CSM adjacent to gel coat

G_c = 0,286
t_{CSM} = 1,112 mm
E_t = 6290 N/mm^2

Total thickness, t_p = 9,132 mm

The effective width of attached plating $2b_1$ from Pt 8, Ch 3,1.7.1 of the Rules for Special Service Craft for single skin construction is:

$$b_1 = 0{,}5b_w + 10t_{ap}$$
$$= 0{,}5 \times 120 + 10 \times 9{,}132$$
$$= 151 \text{ mm}$$

Hence, apply 302 mm attached plating.

Consider typical layup over 'top hat' stiffener:

450 g/m^2 CSM @ G_c = 0,33 – first ply over former
800 g/m^2 WR @ G_c = 0,5
800 g/m^2 WR @ G_c = 0,5
600 g/m^2 UDT @ G_c = 0,54
600 g/m^2 UDT @ G_c = 0,54
800 g/m^2 WR @ G_c = 0,5
800 g/m^2 WR @ G_c = 0,5 – top ply

1.4 Consider the idealised section shown in Fig. 4.1.2.

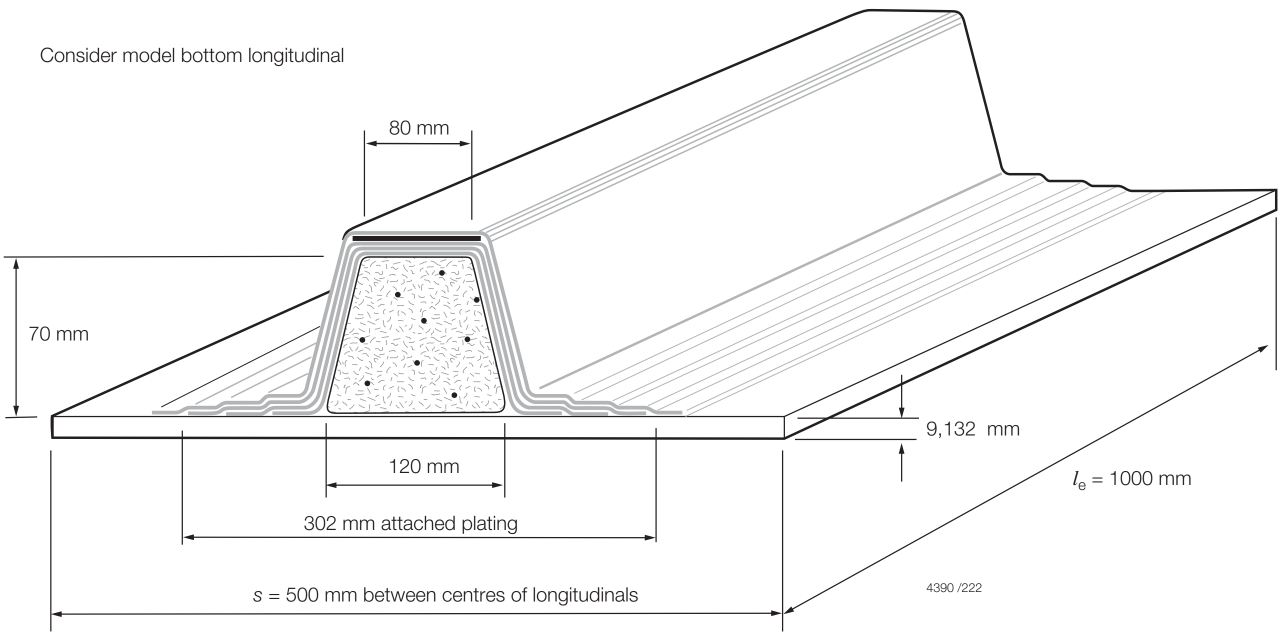

Fig. 4.1.1 'Top-hat' stiffener example model

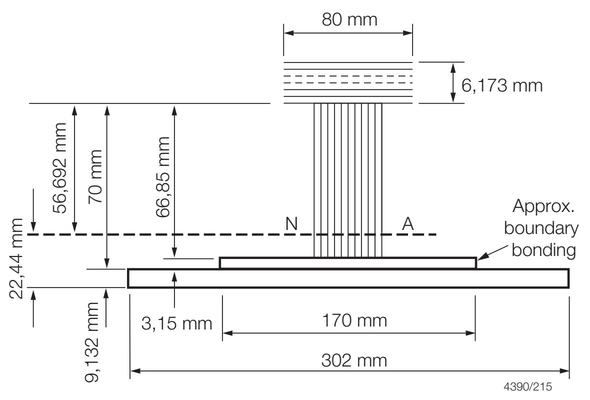

Fig. 4.1.2 Idealised section

1.5 The stiffener bonding is to be in accordance with Pt 8, Ch 3,1.18.6 of the Rules for Special Service Craft and a typical arrangement is shown in Fig. 4.1.3. To simplify the calculation of the stiffness of the overall section the tapered bonding is assumed to be an effective constant thickness. The effective thickness of the bonding is calculated as:

$$t_{bb} = \frac{(4{,}853 \times 25) + (4 + 3 + 2 + 1) \times 0{,}079 \times 15}{25 + (4 \times 15)}$$

$$t_{bb} = \frac{268{,}2}{85} = 3{,}15 \text{ mm}$$

The boundary bonding may be approximated to a thickness of 3,15 mm over an (85 x 2) mm width to account for both flanges. The majority of the flange comprises of woven rovings and it may be assumed that the tensile modulus is 145000 N/mm^2. The discrepancy is negligible since the element is very close to the neutral axis.

The effective depth and width of the web used in the idealised section are:

$$\begin{aligned} d_{web} &= 70 - \text{effective thickness on bonding} \\ &= 70 - 3{,}15 \\ &= 66{,}85 \text{ mm} \\ t_{web} &= 2 \times (0{,}937 + 4 \times 0{,}979) \\ &= 2 \times 4{,}853 \\ &= 9{,}706 \text{ mm} \end{aligned}$$

Now the web consists of two types of reinforcements, namely one ply of CSM and four plies of woven rovings. The majority of the web will be in compression and the overall modulus of elasticity may be calculated in accordance with Pt 8, Ch 3,1.13.5 of the Rules for Special Service Craft.

$$E_{web} = \frac{\Sigma\,(E_{ci}\, t_i)}{\Sigma\, t_i}$$

$$E_{web} = \frac{(0{,}937 \times 7200) + (0{,}979 \times 4 \times 14000)}{0{,}937 + (0{,}979 \times 4)}$$

$$E_{web} = 12687 \text{ N/mm}^2$$

The web may now be treated as a single laminate item having an overall compressive modulus, given above.

1.6 The laminate section modulus calculation is shown in Table 4.1.1. The tabulation consists of each element having the compressive moduli in the section above the neutral axis and tensile moduli below. The actual breadth of each element must be entered to calculate the overall section properties. The tabulation corresponds to the idealised section in Fig. 4.1.2.

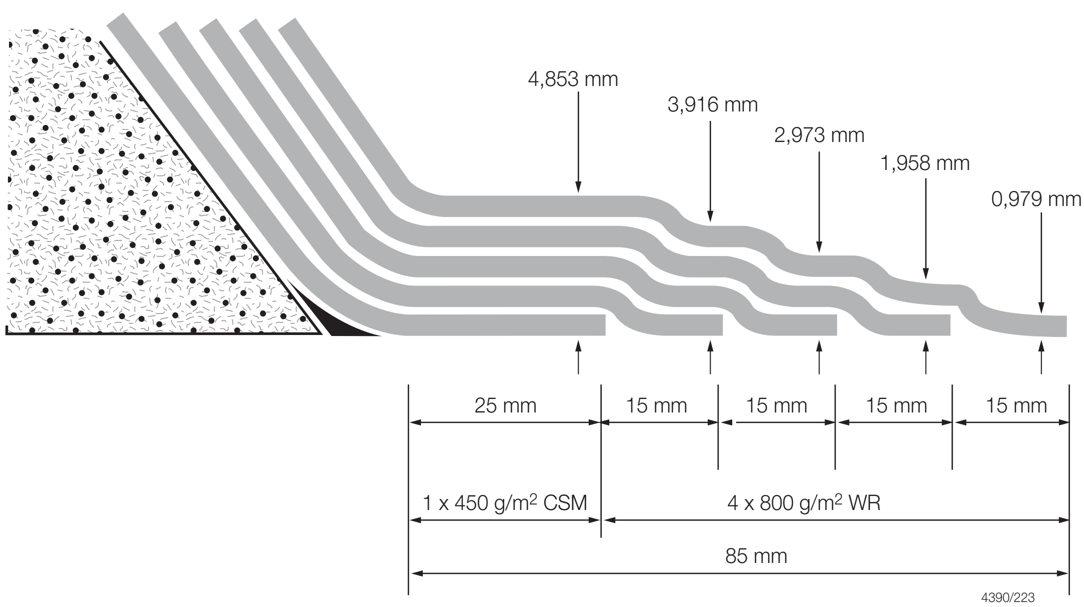

Fig. 4.1.3 Typical stiffener bonding arrangement

Table 4.1.1 Initial tabulation of 'top-hat' stiffener calculations

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Breadth, b (mm)	Lever @ base, x (mm)	E (N/mm^2)	$t.b$	$E.t.b$	$E.t.b.x$	I @ base	EI @ base
Dry, *see* Note	1	WR	0,5	800	0,979	80	84,816	14000	78,32	1096480	92998499	563414,4	7887801805
	2	WR	0,5	800	0,979	80	83,837	14000	78,32	1096480	91925046	550483,0	7706761655
	3	UDT	0,54	600	0,660	80	83,017	20748	52,80	1095494	90944659	363890,1	7549992490
	4	UDT	0,54	600	0,660	80	82,357	20748	52,80	1095494	90221632	358127,2	7430422738
	5	WR	0,5	800	0,979	80	81,538	14000	78,32	1096480	89404238	520706,1	7289885632
	6	WR	0,5	800	0,979	80	80,559	14000	78,32	1096480	88330784	508277,4	7115883045
	7	CSM	0,33	450	0,937	80	79,601	7200	74,96	539712	42961345	474970,0	3419784035
	8	Web	0,5	–	66,85	9,706	45,707	12687	648,85	8231910	376255932	1597160,7	20263177372
	9	bonding	0,5	–	3,15	170	10,707	14500	535,50	7764750	83137178	61832,4	896570245
	10	WR	0,5	800	0,979	302	8,643	14500	295,66	4287041	37050752	22107,1	320553529
	11	CSM	0,33	300	0,625	302	7,840	6950	188,75	1311813	10285266	11609,3	80684330
	12	WR	0,5	800	0,979	302	7,039	14500	295,66	4287041	30174338	14670,7	212724485
	13	CSM	0,33	300	0,625	302	6,236	6950	188,75	1311813	8181119	7347,4	51064249
	14	WR	0,5	800	0,979	302	5,435	14500	295,66	4287041	23297924	8755,5	126954976
	15	CSM	0,33	300	0,625	302	4,632	6950	188,75	1311813	6076971	4056,7	28194272
	16	WR	0,5	800	0,979	302	3,831	14500	295,66	4287041	16421511	4361,7	63245002
	17	CSM	0,33	300	0,625	302	3,028	6950	188,75	1311813	3972824	1737,3	12074400
	18	WR	0,5	800	0,979	302	2,227	14500	295,66	4287041	9545097	1489,3	21594564
	19	CSM	0,33	300	0,625	302	1,424	6950	188,75	1311813	1868677	389,2	2704632
Wet, *see* Note	20	CSM	0,286	450	1,112	302	0,556	6290	335,82	2112333	1174457	138,4	870664
TOTALS					85,305				4436,05	53219882	1194228249		70480944121

NOTE
The crown of the stiffener is considered to be in compression in this example. 'Dry' indicates the face of the stiffener within the hull and 'wet' the outside of the shell laminate, *see* Fig. 4.1.4.

Position of neutral axis above base = $\dfrac{1194228249}{53219882}$ = 22,44 mm above base

Tensile modulus of elasticity of section = $\dfrac{53219882}{4436,05}$ = 11997 N/mm^2

Stiffness EI of section about NA = 4368304 N cm^4/mm^2

1.7 The tabulation considers the entire section and calculates all moments about the base, which is taken to be the outer (wet) surface. The stiffness, EI, of the entire section, about the neutral axis, is determined using the parallel axis theorem:

In general,

$I_{na} = I_{xx} - Ay^2$

$EI_{sect} = \Sigma\, EI_{base} - (\Sigma\, Etb) \times y^2$

where

y = distance of neutral axis above the base (mm)

From the tabulation:

$EI_{sect} = 70480944121 - 53219882 \times (22{,}44)^2$

$= 4368304336$ Nmm^4/mm^2

$EI_{sect} = 4{,}368 \times 10^6$ Ncm^4/mm^2

From Pt 8, Ch 3,1.15 of the Rules for Special Service Craft the individual layer stresses are determined from:

$$\sigma_{ti} = \frac{E_{ti}\, y_i\, M}{\Sigma\,(E_i\, I_i)} \times 10^{-1} \quad \text{N/mm}^2$$

The calculation of the stresses in individual layers becomes:

$$\sigma_{ti} = \frac{2917}{4{,}368 \times 10^6} \times E_i\, y_i \times 10^{-1} \quad \text{N/mm}^2$$

$\sigma_{ti} = 66{,}8 \times 10^{-6} \times E_i\, y_i$ N/mm^2

where

E_i = modulus of elasticity of layer (N/mm^2)

y_i = distance of layer from the neutral axis (mm)

The ‘top-hat’ stiffener is subjected to a load model shown in Fig. 4.1.4. The diagram indicates the areas of tension and compression that exist on either side of the stiffener.

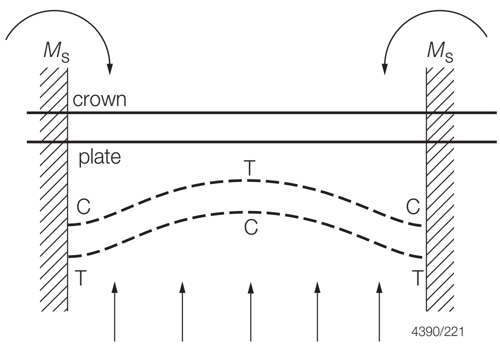

Fig. 4.1.4
Regions of tension (T) and compression (C) in example model

Section 2
Bending moment at fixed end of stiffener

2.1 The generalised stress equation is:

$\sigma_i = 66{,}8 \times 10^{-6} \times E_i\, y_i$ N/mm^2

The ultimate material properties may be found from Tables 3.1.1 and 3.1.2 in Pt 8, Ch 3 of the Rules for Special Service Craft and the limiting stress fractions from Table 7.3.1 in Pt 8, Ch 3 of the Rules for Special Service Craft.

2.1.1 Consider the crown of the stiffener:

(a) Consider the WR (G_c = 0,5) in compression:

E_c = 14000 N/mm^2

y_i = 85,305 – 22,44

= 62,865 mm

$\sigma_{WR\ comp} = 66{,}8 \times 10^{-6} \times 14000 \times 62{,}865$

= 58,8 N/mm^2

$\sigma_{WR\ ucs}$ = 147 N/mm^2

Stress fraction = 58,8/147 = 0,40 hence reject.

(b) Consider the UDT (G_c = 0,54) in compression:

E_c = 20748 N/mm^2

y_i = 85,305 – 22,44 – (2 x 0,979)

= 60,907 mm

$\sigma_{UDT\ comp} = 66{,}8 \times 10^{-6} \times 20748 \times 60{,}907$

= 84,4 N/mm^2

$\sigma_{UDT\ ucs}$ = 279 N/mm^2

Stress fraction = 84,4/279 = 0,303 hence acceptable.

(c) Consider the CSM (G_c = 0,33) over the stiffener former in compression:

E_c = 7200 N/mm^2

y_i = (85,305 – 22,44) – (4 x 0,979) – (2 x 0,66)

= 57,629 mm

$\sigma_{CSM\ comp} = 66{,}8 \times 10^{-6} \times 7200 \times 57{,}629$

= 27,7 N/mm^2

$\sigma_{CSM\ ucs}$ = 122 N/mm^2

Stress fraction = 27,7/122 = 0,227 hence acceptable.

2.1.2 Consider the loaded face of the shell:

(a) Consider the wet surface CSM (G_c = 0,286) in tension:

E_t = 6290 N/mm^2

y_i = 22,44 mm

$\sigma_{CSM\ tension} = 66{,}8 \times 10^{-6} \times 6290 \times 22{,}44$

= 9,4 N/mm^2

$\sigma_{CSM\ uts}$ = 91 N/mm^2

Stress fraction = 9,4/91 = 0,10 hence acceptable.

Due to such a low stress fraction the adjacent CSM (G_c = 0,33) will also be acceptable.

(b) Consider the WR (G_c = 0,5) in tension:

E_t = 14500 N/mm^2

y_i = 22,44 – 1,112 – 0,625

= 20,703 mm

$\sigma_{WR\ tension} = 66{,}8 \times 10^{-6} \times 14500 \times 20{,}703$

= 20,05 N/mm^2

$\sigma_{WR\ uts}$ = 190 N/mm^2

Stress fraction = 20,05/190 = 0,105 hence acceptable.

2.2 However, the conclusion is that the compressive stress fraction in the WR in the crown of the stiffener is unacceptable. A number of options exist, which include:

(a) The use of higher strength materials such as carbon fibre or aramid reinforcements.
(b) Add UDT reinforcements in the crown of the stiffener.
(c) Laminate local collars at the end of the stiffeners to increase the section stiffness. This is usually labour intensive and not weight efficient.

2.3 Logically, for this example, the easiest solution is to add UDT reinforcements in the crown of the stiffener. Two additional UDT reinforcements have been included in the revised arrangement. The effect on the section stiffness of the revised schedule is shown in Table 4.2.1.

2.4 Recalculation of stress in the WR reinforcement in the stiffener crown using the revised section stiffness of 5200996 Ncm/mm^2:

$$\sigma_{ti} = \frac{2917}{5200996} \times E_i\, y_i \times 10^{-1} \text{ N/mm}^2$$

$$\sigma_{ti} = 56{,}09 \times 10^{-6} \times E_i\, y_i \text{ N/mm}^2$$

Consider the WR (G_c = 0,5) in the crown of the stiffener in compression:

$$E_c = 14000 \text{ N/mm}^2$$
$$y_i = 86{,}625 - 24{,}926 = 61{,}7 \text{ mm}$$
$$\sigma_{\text{WR comp}} = 56{,}09 \times 10^{-6} \times 14000 \times 61{,}7 = 48{,}4 \text{ N/mm}^2$$
$$\sigma_{\text{WR ucs}} = 147 \text{ N/mm}^2$$

Stress fraction = 48,4/147 = 0,329 hence acceptable.

2.5 Re-consider the outermost UDT (G_c = 0,54) in compression:

$$E_c = 20748 \text{ N/mm}^2$$
$$y_i = 86{,}625 - 24{,}926 - 0{,}979 = 60{,}720 \text{ mm}$$
$$\sigma_{\text{UDT comp}} = 56{,}07 \times 10^{-6} \times 20748 \times 60{,}720 = 70{,}66 \text{ N/mm}^2$$
$$\sigma_{\text{UDT ucs}} = 279 \text{ N/mm}^2$$

Stress fraction = 70,66/279 = 0,25 hence acceptable.

2.6 The example demonstrates that the additional two UDT's in the crown increases the section stiffness by 19 per cent and is accompanied by a movement in the neutral axis from 22,44 – 24,926 mm above the base. The stress fraction in the woven roving in the crown is reduced from 0,4 to 0,329 and meets the Rule requirement of 0,33.

Considerable care must be exercised when additional material radically affects the position of the neutral axis. For this reason the stress in the outermost UDT's has also been re-calculated and found to be satisfactory.

2.7 Where aramid reinforcements are being used then special consideration must be given to the compressive properties. For comparison purposes aramid reinforcements, at a fibre content of 0,45, typically have the following properties:

	Tension	Compression
Ultimate strength (N/mm^2)	300	100
Elastic modulus (N/mm^2)	21000	17000

2.8 The radical reduction in ultimate compressive strength may prove to be unsuitable in the crown of the stiffener at the end or in the panel at mid span. Designs which feature aramid fibres in the outer plies of the panel, in an attempt to make use of the superior impact properties, must be checked at mid span for compression in the individual layers. This also applies to hybrid reinforcements containing aramid fibres. These reinforcements have one off properties of higher than one of the constituent fibres however, in service the individual allowable strains for each fibre reinforcement should not be exceeded.

2.9 In accordance with Pt 8,Ch 3,1.5.1 of the Rules for Special Service Craft, it is of paramount importance that the strain compatibility of the component materials is carefully considered.

2.10 Consider typical values of apparent strain, ε_a, at failure for the following materials in laminate form:

	Tension	Compression
'E' glass	1,3%	1,05%
Carbon fibre	0,9%	0,55%
Aramid fibre	1,3%	0,60%

2.11 The actual strain permissible is controlled by the material with the lowest apparent strain. The level of strain depends upon whether the reinforcements are in tension or compression and depends on their relative positions within the laminate. Consequently if, for example, a carbon fibre reinforcement is used in the crown of the stiffener then the compression strain must be constrained to a maximum of 0,33 x 0,55 per cent, i.e., 0,297 per cent. Therefore, the corresponding allowable stress in the other reinforcements must be related to the strain in the reinforcement relative to its position away from the neutral axis and that of the carbon fibre reinforcement, e.g.:

$$\varepsilon_{\text{limitWR}} = \frac{\varepsilon_{\text{allowable carbon}} \times y_{\text{WR}}}{y_{\text{carbon}}}$$

2.12 Other materials incoporated into stiffening members requiring strain compability consideration are plywoods, timbers, etc., which have very differing strains at failure dependent upon the direction of the grain.

Table 4.2.1 Revised tabulation of 'top-hat' stiffener calculations including additional uni-directional reinforcements

	Ply No.	Description	G_c	Weight (g/m^2)	t (mm)	Breadth, b (mm)	Lever @ base, x (mm)	E (N/mm^2)	$t.b$	$E.t.b$	$E.t.b.x$	I @ base	EI @ base
Dry, *see* Note	1	WR	0,5	800	0,979	80	86,136	14000	78,32	1096480	94445853	581087,7	8135228350
	2	UDT	0,54	600	0,660	80	85,316	20748	52,80	1095494	93463200	384323,6	7973946157
	3	WR	0,5	600	0,979	80	84,497	14000	78,32	1096480	92648722	559184,3	7828580341
	4	UDT	0,54	600	0,660	80	83,677	20748	52,80	1095494	91667685	369699,1	7670516637
	5	UDT	0,54	600	0,660	80	83,017	20748	52,80	1095494	90944659	363890,1	7549992490
	6	WR	0,5	800	0,979	80	82,198	14000	78,32	1096480	90127915	529169,8	7408376853
	7	UDT	0,54	600	0,660	80	81,378	20748	52,80	1095494	89149143	349663,5	7254818749
	8	WR	0,5	800	0,979	80	80,559	14000	78,32	1096480	88330784	508277,4	7115883045
	9	CSM	0,33	450	0,937	80	79,601	7200	74,96	539712	42961345	474970,0	3419784035
	10	web	0,5	–	66,850	9,706	45,707	12687	648,85	8231910	376255932	1597160,7	20263177372
	11	bonding	0,5	–	3,150	170,000	10,707	14500	535,50	7764750	83137178	61832,4	896570245
	12	WR	0,5	800	0,979	302	8,643	14500	295,66	4287041	37050752	22107,1	320553529
	13	CSM	0,33	300	0,625	302	7,840	6950	188,75	1311813	10285266	11609,3	80684330
	14	WR	0,5	800	0,979	302	7,039	14500	295,66	4287041	30174338	14670,7	212724485
	15	CSM	0,33	300	0,625	302	6,236	6950	188,75	1311813	8181119	7347,4	51064249
	16	WR	0,5	800	0,979	302	5,435	14500	295,66	4287041	23297924	8755,5	126954976
	17	CSM	0,33	300	0,625	302	4,632	6950	188,75	1311813	6076971	4056,7	28194272
	18	WR	0,5	800	0,979	302	3,831	14500	295,66	4287041	16421511	4361,7	63245002
	19	CSM	0,33	300	0,625	302	3,028	6950	188,75	1311813	3972824	1737,3	12074400
	20	WR	0,5	800	0,979	302	2,227	14500	295,66	4287041	9545097	1489,3	21594564
	21	CSM	0,33	300	0,625	302	1,424	6950	188,75	1311813	1868677	389,2	2704632
Wet, *see* Note	22	CSM	0,286	450	1,112	302	0,556	6290	335,82	2112333	1174457	138,4	870664
TOTALS					86,625				4541,65	55410871	1381181352		86437539378

NOTE: 'Dry' indicates the face of the stiffener within the hull and 'wet' the outside of the shell laminate, *see* Fig. 4.1.4. Consider the crown of the stiffener in compression.

Position of neutral axis above base = $\dfrac{1381181352}{55410871}$ = 24,926 mm above base

Tensile modulus of elasticity of section = $\dfrac{55410871}{4541,65}$ = 12201 N/mm^2

Stiffness EI of section about NA = 5200996 N cm^4/mm^2

Section 3
Web thickness to meet shear requirement

3.1 Ultimate shear stress from Table 3.1.2 in Pt 8, Ch 3 of the Rules for Special Service Craft. From the web thickness (4,853 mm) given in 1.5 and the web laminate schedule given in Fig. 4.1.3 (i.e. total weight of 3650 g/m^2) the effective glass content may be calculated, by transforming the relationship given in Pt 8, Ch 4,1.6.1 of the Rules for Special Service Craft. The effective glass content of the web is therefore 0,47.

$$\tau_S = 80\,G_c + 38 = 76 \text{ N/mm}^2$$

From Pt 8, Ch 7, Table 7.3.1 of the Rules for Special Service Craft.
Limiting shear stress fraction = 0,33
Limiting shear stress = 0,33 x 76 = 25,08 N/mm^2.

3.2 The shear stress requirement is given in Pt 8, Ch 3,1.14.3 of the Rules for Special Service Craft. By setting the shear stress to the limiting shear stress the equation may be rearranged:

$$t_w = F_S/(2 \times d_w \times \tau_S) \text{ mm}$$

The actual shear load is given in Pt 8, Ch 3,1.14.2 of the Rules for Special Service Craft.

$$F_s = \phi_S\, p\, s\, l_e \text{ N}$$

The shear stress coefficient is obtained from Table 3.1.5 in Pt 8, Ch 3 of the Rules for Special Service Craft.

$$F_s = 0{,}5 \times 70 \times 500 \times 1 = 17500 \text{ N}$$

Consequently, the minimum web thickness to meet the Rule requirement is:

$$t_w = 17500/(2 \times 70 \times 25{,}08) = 4{,}98 \text{ mm}$$

The actual web thickness is 4,853 mm. The deficiency is only 0,127 mm and is considered acceptable.

3.3 Finally, check the minimum Rule requirement for web thickness. From Pt 8, Ch 3,1.16.2 of the Rules for Special Service Craft.

$$t_w = \frac{0{,}025 d_w + 1{,}1}{1{,}3 f_w + 0{,}61}$$

For a web depth of 70 mm and fibre content of 0,47 the minimum web thickness is 2,33 mm. Hence the minimum requirement is fulfilled.

Section 4
Calculation of deflection

4.1 The deflection is calculated from Pt 8, Ch 3,1.14.5 of the Rules for Special Service Craft. From the tabulation the overall section stiffness is $(EI)_S$ = 5200996 Ncm^4/mm^2

$$\delta_s = \frac{\phi_S\, p\, s\, l^4}{(EI)_S} \times 10^5 \text{ mm}$$

$$\delta_s = \frac{1}{348}\;\frac{70 \times 500 \times 1^4}{5200996} \times 10^5 \text{ mm}$$

$$\delta_s = 1{,}93 \text{ mm.}$$

4.2 The limiting span/deflection ratio is given in Table 7.2.1 in Pt 8, Ch 7 of the Rules for Special Service Craft and typically for a bottom longitudinal (not in the slamming zone) the ratio required is 150.

Span/deflection ratio = length/mid-point deflection
= 1000/1,7
= 588 hence acceptable.

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Guidance Notes for the Classification of Special Service Craft

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Chapter Contents

Guidance Notes

GUIDANCE NOTES ON DESIGN DETAILS

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Guidance Notes

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Section 1
Introduction

1.1 Purpose of the Guidance Notes

1.1.1 With the advent of novel and high speed craft types the need for good structural detail has never been more important. Most structural failures that occur in the service life of a craft result from fatigue. A considerable amount of published data exists for more conventional steel vessels, however, little or no such data exists for the novel or high speed craft constructed from aluminium alloy or composite materials. Lloyd's Register (hereinafter referred to as LR) has amassed considerable knowledge in respect of structural detail which has demonstrated satisfactory service experience in resisting structural failure from fatigue. The details contained within these Guidance Notes are therefore provided to assist Builders and designers in identifying a minimum level of design detail which has provided acceptable levels of resistance to structural failure arising from fatigue.

1.1.2 It is not intended that the details contained within these Guidance Notes are the only solution to a particular structural design. Alternative structural details that have demonstrated satisfactory service experience will be acceptable.

1.2 General

1.2.1 Quality of detail design is fundamental if the craft's envisaged design life is to be attained. Experience over the past two decades, when structural concepts were revolutionised and aspects such as speed greatly increased, clearly indicated that areas of detail design became more prone to fatigue cracking with the traditional structural arrangements for details being used at that time.

1.2.2 Service experience has shown that provided the general concepts of a structural design are adequate then success or failure in structural terms will depend on the quality of detail design.

1.2.3 In general, the problems associated with aspects of detail design are those relating to fatigue ageing and failure.

1.2.4 Fatigue is failure under repeated loads. There are three phases in a fatigue fracture: crack initiation, crack propagation, and fracture. These phases are not completely separable. The process may be described as the formation of a crack, because of repeated local plasticity, its progression until a critical size is reached, where upon the structure fails. Fatigue accounts for a large percentage of all service failures.

1.2.5 A structural element can be subjected to various kinds of loading conditions, including fluctuating stress/strain, fluctuating temperature (thermal stress/strain), or any of these in a corrosive environment or at elevated temperatures. Most service failures occur as a result of tensile stresses.

1.2.6 Fatigue cracks generally initiate at high stress locations such as structural discontinuities, weld toes, matting in connections, etc. As these cracks propagate the ultimate load carrying capability of the structure is reduced until sufficient fatigue damage is accumulated for the structure to fail at normal working loads. Since fatigue cracks can be possible points of initiation for catastrophic failures or costly craft repairs, it is essential that fatigue is given more detailed consideration in the design of the structure.

1.2.7 Fatigue ageing of structural components is an accumulative process which is largely due to the environment and the loads experienced. An important realisation is that it is inevitable and where stress concentrations are present in association with significant magnitudes of stress variation then fatigue cracking will, in general, occur. Factors which influence performance, in that they affect the magnitude of stress ranges and provide stress concentrations, are as follows:
(a) The loading experienced.
(b) The quality of detail design.
(c) The selecting of the type and grade of material.
(d) The standard of workmanship in the craft construction.
(e) Corrosion rates and magnitudes (metallic structures).
(f) Erosion rates and magnitudes (composite structures).

1.2.8 Since the fatigue properties of higher tensile strength metallic materials are, in general, similar to those of the basic grade materials, the higher allowable stress magnitudes could entail a shorter fatigue life in standard details. Assuming that the fatigue life is a function of the stress range to the third power, it is clear that detail design requires special consideration to reduce the effects of stress concentrations. If higher tensile strength materials are incorporated and hence higher stress levels are accepted, then structural details, which would have been acceptable in mild steel structure manufactured from the basic grade material, might not be adequate.

1.2.9 The occurrence of cracking in craft is of prime concern from both a safety and maintenance point of view. Experience has shown that fatigue cracks in craft structures are normally of a self limiting nature. However, the existence of fatigue cracking may, if not repaired, render the structure susceptible to subsequent brittle or fast fracture. Thus both types of cracks are significant from a maintenance point of view. Fatigue cracks, if not repaired, may also initiate catastrophic failure as a consequence of the more extensive use of structural optimisation leading to a decrease in the level of structural redundancy.

Section 2
Fatigue – General considerations

2.1 Basis of the Guidance Notes

2.1.1 In assessing fatigue performance, the effect of cyclic loading should be taken into consideration. The types of cyclic loading experienced in service, will, in general, depend upon the size, type and speed of the craft. Cyclic wave induced loads created by the passage of waves along the craft sides and the associated local structural response create the highest risk for fatigue damage and cracking for large craft whereas, the major consideration for small high speed craft will relate to impact considerations, hard spots and discontinuities in the structure, etc.

2.1.2 Loading associated with bottom structures, in terms of hull girder response and local pressure variation, are heavily influenced by the length of waves and their direction in relation to the craft length and draught. Similarly, the deck structure is exposed to hull girder loads in response to relatively longer waves and cargo local loads arising from craft responses. Alternatively, these can be associated with structural discontinuities and slamming in shorter waves.

2.1.3 Deck and bottom longitudinal structure require attention to detail design and structural continuity to reduce the effects of stress concentration. Depending on the type of craft, the side shell structure may be exposed to dynamic loading from the internal pressure head from storage of consumables or cargo, in association with wave induced pressure variations, resulting in high cycle local bending stresses applied to the longitudinals and connection details at the transverse bulkhead stiffeners. This may transfer moments resulting in further increased stresses in the side longitudinals.

2.1.4 Every stress concentration and welded joint is a potential source of fatigue cracking and the design, taking note of symmetry, should reflect this. To ensure the structural integrity of the stiffening members particular attention should be given to the detail design. This document provides initial design guidance on fatigue and includes recommendations for the improvement of welded joint fatigue strength, or the bonded joint fatigue strength in the case of composite structures.

2.1.5 The fatigue strength of a structural detail is dependent on the following factors:
(a) The direction of the fluctuating stress relative to the detail.
(b) The location of initiating crack in the detail.
(c) The geometrical arrangements and relative proportion of the detail.
It may also depend on:
(d) The material (unless welded).
(e) The method of fabrication.
(f) The degree of inspection.

2.2 Fatigue mechanism

2.2.1 Fatigue damage starts prior to the initiation of a crack. With repeated loading, localised regions of slip (plastic deformation) develop. These deformations are accentuated by repeated loading, until a discernable crack finally appears.

2.2.2 The initial cracks form along slipped planes. The crack is crystallographically oriented along the slip plane for a short distance. This is sometimes referred to as Stage I crack growth. Eventually the crack propagation direction becomes macroscopically normal to the maximum tensile stress. This is referred to as Stage II crack propagation, and it comprises most of the crack propagation life.

2.2.3 The relative cycles for crack initiation and propagation depend on the applied stress. As the stress increases, the crack initiation phase decreases. At very low stresses (high cycle fatigue), therefore, most of the fatigue life is utilised to initiate a crack. At very high stresses (low cycle fatigue), cracks form very early. The separation of high and low cycle fatigue is not clear-cut. Generally, the low cycle region is that which results from stresses that are often high enough to develop significant plastic strains. It is usually assumed that the separation zone for low and high cycles is of the order of $10^4 – 10^5$ cycles to failure.

2.2.4 There are visual differences between high cycle (low stress) and low cycle (high stress) fatigue. In the latter, deformation resembles that seen with unidirectional loading. Strain hardening can occur and the slip bands are coarse. In high cycle fatigue, the slip bands are usually very fine.

2.3 Allowable stresses

2.3.1 For a particular craft component the allowable stresses should be in accordance with the requirements of LR's *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft).

2.4 Design loads

2.4.1 Applied design loads must take into consideration the appropriate environmental and dynamic conditions. Such loads are indicated in Part 5 of the Rules for Special Service Craft.

2.4.2 Realistic assessment of the fatigue loading is crucial to the estimation of fatigue life. Little or no published data for loading exists for the types of craft covered by the Rules for Special Service Craft. LR is conducting research in this field, the results of which will form the basis of Rules for Special Service Craft requirements in the future.

2.5 Stress concentrations

2.5.1 The design, fabrication and construction of all structural details should be based on procedures and processes to minimise stress concentrations.

2.5.2 Fatigue strength is seriously reduced by the introduction of a stress raiser such as a notch, of the method of termination of stiffeners and brackets, etc., or a hole. Since actual hull structure elements invariably contain stress raisers like fillet welds, end brackets, cut-outs, etc., it is not surprising to find that fatigue cracks in structural parts usually start at such geometrical irregularities. One of the most effective ways of minimising fatigue failure is by the reduction of avoidable stress raisers through careful design and the prevention of accidental stress raisers by careful processing and fabrication. While this section is concerned with stress concentrations resulting from geometrical discontinuities, stress concentration can also arise from surface roughness and metallurgical stress raisers such as porosity, inclusions, local overheating in grinding and decarburisation, etc., as appropriate to the construction material.

2.5.3 The effect of stress raisers on fatigue under uniaxial loading is that;

(a) there is an increase or concentration of stress at the root of the notch,
(b) a stress gradient is set up from the root of the notch,
(c) a triaxial state of stress is produced.

2.5.4 The ratio of the maximum stress to the nominal stress is the Stress Concentration Factor.

2.5.5 Values of the stress concentration factor will vary depending upon:

(a) the severity of the notch,
(b) the type of notch,
(c) the material,
(d) the type of loading, and
(e) the stress level.

2.6 Stiffness

2.6.1 Abrupt changes in stiffness of the structure should be avoided as they can induce local stress concentrations and reductions of fatigue life.

2.7 Vibration

2.7.1 If possible, precautions should be taken in the design against the possibility of excessive structural vibration being induced, for example, by machinery. This would entail investigation of the natural frequencies of the panel members and of the sources of excitation.

2.8 Potential modes of failure

2.8.1 The potential modes of fatigue failure are dependent upon the direction of the applied stress relative to the position of the weld and the position of stress concentrations due to structural discontinuities.

2.8.2 For longitudinal butt welds in plates, dressed flush, and lying parallel to the direction of applied stress, the initiation of potential fatigue failures is expected to be found at weld defect locations. In the 'as-welded' condition, fatigue cracks may be initiated at the weld start-stop positions or, weld surface ripples.

2.8.3 For transverse butt welds in plates, essentially perpendicular to the direction of applied stress, the fatigue strength depends largely upon the shape of the weld profile. Fatigue cracks normally initiate at the weld toe.

2.8.4 Cruciform fillet weld joints associated with the four way connection of plate or stiffeners, may be separated into two distinct types depending on whether or not the fillet weld transmits direct load i.e. non-load carrying or load carrying cruciform joints. In the case of the non-load carrying cruciform joint, the fatigue crack will initiate at the weld toe and propagate through the thickness of the load bearing plate in a plane perpendicular to the direction of the applied stress.

2.8.5 In load carrying cruciform joints, in addition to the weld toe, acute stress concentration occurs at the root of the fillet weld and generally fatigue cracks are initiated at the root of the weld and propagate through the weld throat. The fatigue life of such connections can be improved either by increasing the throat size of the fillet weld or by requiring improved weld penetration. In high stress regions however, such measures may not be adequate and there is then a need to specify a full penetration weld in order to achieve the necessary fatigue life for the joint.

2.8.6 Tee joints, since they represent a semi-cruciform joint in a three way connection of plates or stiffeners, would be expected to demonstrate similar fatigue characteristics to the load bearing cruciform joint. However, if bending stresses are induced in the base plate material of the tee, which are of a similar or greater magnitude than the direct stress in the tee, then a fatigue crack may initiate in the base plate at the toe of the fillet weld and propagate through the base plate.

2.8.7 Where tee or cruciform connections employ full penetration welds, and the plate material is subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specific through thickness properties, as detailed in Ch 3,8 of the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred as the Rules for Materials).

2.8.8 For welded stiffeners and girders, fatigue cracks can be expected to be initiated at weld toes and may be associated with local stress concentrations at the weld ends of connecting end brackets or stiffeners.

2.8.9 The most common sites for potential fatigue cracks therefore are:

(a) Toes and roots of fusion welds.
(b) Machined corners.
(c) Drilled holes, cut-outs or other openings.

2.8.10 The main conditions affecting fatigue performance are:
(a) High ratios of dynamic to static loads.
(b) Loading frequency.
(c) Material selection.
(d) Welding.
(e) Complexity of joint detail.
(f) Environment.

2.8.11 For craft operating for long periods in low air temperatures, or high temperatures for composites, the material of exposed structures will need to be specially considered.

2.9 Welds

2.9.1 Some commonly used weld details have low fatigue strength. This applies not only to joints between members, but also to any attachment to a loaded member, whether or not the resulting connections are considered to be structural.

2.9.2 The heat-affected zone (HAZ) is of great importance to the fatigue strength of welds because this is usually the region where a fatigue crack will develop. Moreover, when the reinforcement of a butt weld is not removed, or when fillet welds are used, a resulting sudden change of section occurs, and stress concentrations occur at the weld toe.

2.9.3 For the specification of welding and structural details, *see* Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively.

2.10 S-N curves

2.10.1 A material's fatigue characteristics are fatigue strength and fatigue limit.

2.10.2 The fatigue strength is the stress value beyond which the material will fail at a specified number of stress cycles.

2.10.3 The fatigue limit is the fatigue strength corresponding to an infinite number of stress cycles.

2.10.4 The S-N curve represents the dependence of the life of the 'specimen' in a number of cycles, N, to the maximum applied stress, S. N is usually taken (unless specified otherwise) as the number of stress cycles to cause a complete fracture in the 'specimen'.

2.10.5 Usually no distinction is made between the number of cycles to initiate a crack and the number of cycles to propagate the crack completely through the specimen, although it can be appreciated that the number of cycles for crack propagation will vary with the dimensions of the specimen. Fatigue tests for high cycle fatigue are usually carried out for 10^5 – 10^7 cycles and sometimes to 5 x 10^8 cycles for non-ferrous metals. For a few important engineering materials such as steel and titanium, the S-N curve becomes horizontal at a certain limiting stress. Below this limiting stress, which is called the fatigue limit, or endurance limit, the material can presumably endure an infinite number of cycles without failure.

2.11 Complexity of joint detail

2.11.1 Complex joints frequently lead to high stress concentrations due to local variations on stiffness and load path. Whilst these may have little effect on the ultimate static capacity of the joint they can have a severe effect on fatigue resistance.

2.11.2 If fatigue control is the dominant criteria, the member cross-sectional shape should be selected to ensure smoothness and simplicity of joint design, so that stresses can be calculated and adequate standards of fabrication and inspection assured.

2.11.3 The best fatigue behaviour will be obtained by ensuring that the structure is detailed and constructed so that stress concentrations are kept to a minimum and that, where possible, the elements may deform without introducing secondary deformations and stresses due to local restraints.

2.11.4 Stresses may be reduced by increasing the thickness of the parent metal and this would theoretically increase fatigue life due to a reduction of the nominal stresses. However, it should be borne in mind that fatigue strength decreases, in general, with increasing thickness.

2.12 Surface properties

2.12.1 Since fatigue failure is dependent on the condition of the surface, anything that changes the fatigue strength of the surface material will greatly alter the fatigue properties.

2.12.2 As an example most mechanically finished metallic parts have a shallow surface layer in residual compression. Aside from the effect on surface roughness, the final surface finishing process will be beneficial to fatigue when it increases the depth and intensity of the compressively stressed layer and detrimental when it decreases or removes this desirable layer. Thus sandblasting, glass bead peening, burnishing, and other similar operations generally improve fatigue properties.

2.13 Residual stress

2.13.1 Residual stresses arise when plastic deformation is not uniform throughout the entire cross section of the detail being deformed. They therefore comprise a system of internal stresses in the material balanced within the material itself and can exist in the absence of any external loading. Thus if there is an area of tensile residual stress in any cross section at one part of a material there must be a residual compressive stress at some other point. There would in addition be a variation of stress through the thickness of the material, particularly for thicker sections.

2.13.2 In a welded joint residual stresses are induced as a consequence of local heating and cooling cycles associated with the welding procedure and in particular the shrinkage of the weld metal. The actual situation in a welded joint is complicated by practical factors such as the type and size of joint, the welding process used and the weld procedure. In a butt weld for example, high residual tensile stress will exist in the direction of the weld and at right angles to it. In the case of multi-pass or high energy welding these residual stresses may reach the level of the yield strength of the material. As such tensile residual stresses can occur in locations where fatigue cracks are likely to initiate, it will be appreciated that they can lead to a proportional reduction in the fatigue strength of a joint when it is subjected to additional dynamic tensile loads.

2.14 Compressive residual stress

2.14.1 The formation of a favourable compressive residual-stress pattern at the surface is probably the most effective method of increasing fatigue performance. As indicated in 2.13, residual stresses are locked-in stresses which are present in a part which is not subjected to an external force. Only macro-stresses, which act over regions which are large compared with the grain size, are considered here.

2.14.2 In general, for a situation where part of the cross section is deformed plastically while the rest undergoes elastic deformation, the region which was plastically deformed in tension will have a compressive residual stress after unloading, while the region which was deformed plastically in compression will have a tensile residual stress when the external force is removed. The maximum value of residual stress which can be produced is equal to the elastic limit of the metal.

2.14.3 The high compressive residual stresses at the surface must be balanced by tensile residual stresses over the interior of the cross section.

2.14.4 The improvement in fatigue performance, which results from the introduction of surface compressive residual stress, will be greater when the loading is one in which a stress gradient exists than the case when no stress gradient is present.

2.14.5 It is important to recognise that improvements in fatigue properties do not automatically result from the use of shot peening or surface rolling. It is possible to damage the surface by excessive peening or rolling.

2.14.6 In order for the desirable effect of surface cold working to be maintained, the cold-working process must be accomplished in the final heat-treated condition and subsequent thermal treatment eliminated when feasible and closely controlled when essential. Exposure of cold-worked surfaces to elevated temperature initially results in stress relief of the plastically deformed zone and ultimately in recovery or perhaps re-crystallisation of the work-hardened area, with complete loss of the desirable residual stress gradient.

2.15 Grinding

2.15.1 There are some processes that are capable of developing high localised surface temperatures which are often difficult to detect and occasionally are responsible for a failure in service. Grinding can be one of these processes.

2.15.2 The rapid quenching of the material immediately below the grinding wheel by the large mass of cold metal can produce cracks or ‘check’. High strength steels (for which grinding is most often used) are particularly sensitive to grinding techniques.

Section

Section 1 Introduction

1.1 Definition

1.1.1 **Critical areas** can be defined as locations that, by reason of stress concentration, alignment/discontinuity and corrosion will have a higher probability of failure during the life of the craft than the surrounding structures. **Critical locations** are defined as the specific locations within the critical area that can be prone to fatigue damage for which design improvements are provided.

1.2 General

1.2.1 In order to assist the designer to minimise fatigue failures, LR has developed an extensive database on structural detail design aspects.

1.2.2 Utilising the results from detailed finite element analyses for an extensive range of structural details it has been possible to examine a variety of configurations for each detail thereby enabling a grading to be made of their relative fatigue performance.

1.2.3 The outcome from some of this work has been condensed into these Guidance Notes. It is intended as a conservative approach to improving the fatigue life performance of structural details.

1.2.4 The designer may therefore, using these Guidance Notes, readily upgrade the detail design arrangements to provide a higher fatigue performance configuration.

1.2.5 It is intended that the detail design database given in Chapter 4 will be extended to incorporate further detail arrangements, to reflect in-service experience of their fatigue performance, design and construction practice, as well as any significant data made available from research studies.

1.2.6 In addition, guidance is provided to the designer and Builder on other methods to improve the fatigue life performance of the structural detail such as detail geometry, construction tolerances, welding sequence, weld defect, weld dressing, etc.

1.3 Application

1.3.1 The detail design improvements provided in these Guidance Notes are applicable to all grades of steel, commonly used aluminium alloys and composite structures. This is because the fatigue life improvement will be achieved through the suggested change of **geometry** which will reduce the stress concentrations and the **improved construction** requirements which will improve the performance throughout the design lifetime of the structural detail under the expected stress variations.

1.3.2 In areas where **mild steel** and basic grade aluminium may be used a number of the suggested detail improvements may not be necessary due to the lower stress ranges that the details are designed to experience. However, in areas where **higher tensile steel** (HTS) or higher strength grade aluminium are used, the operating stresses will generally be higher. Therefore the detail improvements suggested may become necessary in order to meet the fatigue strength of the structure.

1.3.3 **Alternative structural arrangements** will, in general, be acceptable provided it can be demonstrated, that a satisfactory fatigue life performance will be maintained throughout the design life span. In addition the structural arrangements and scantlings are to satisfy the Rules for Special Service Craft.

1.3.4 Where suggested values are indicated regarding geometries or scantlings, these are given as guidance.

Section 2 Fatigue strength improvement methods

2.1 General

2.1.1 In general, the presence of a weld or a bonded joint in a structural component represents a possible weakness with regard to both brittle fracture and fatigue life. The low fatigue life of welded details can be considered as a limiting factor for the design of more efficient structures, in particular, since the fatigue strength of steel and aluminium materials does not increase with the yield strength.

2.1.2 Upgrading of the fatigue life of a structural detail can be achieved in a number of ways as follows:

Design Stage

- By adopting good detail design configuration, i.e., by the provision of soft connections, the geometrical stress concentration factor due to the geometrical discontinuity may be reduced to a satisfactory level.
- By increasing the local scantlings, in particular those of the plate in which the potential crack sites are located, to reduce the local hot spot stresses.
- By modifying the structural load path and/or reducing the structural load level by the provision of additional load carrying members.

Fabrication Stage

- By improving the fatigue life of the detail by using an improvement method.

2.1.3 It is LR's intention to promote the Design Stage method for fatigue strength improvement of a craft's structural details. Fabrication stage improvement methods should only be considered as remedial measures, and subjected to strict quality control procedures. Where a fabrication stage improvement method is planned at the design stage, it is to be specially considered by LR to ensure that a satisfactory level of fatigue strength improvement is achieved.

2.2 Significant variables affecting fatigue strength improvement methods

2.2.1 The significant variables affecting the fatigue strength of a craft's structural details are reviewed:

- The geometrical notch at the weld toe region is normally the most fatigue critical area. Welded joints inherently contain a number of defects, most of which are so sharp that they start growing as fatigue cracks when the structure is subjected to dynamic loads, thus eliminating the crack initiation stage of the fatigue life.
- The fatigue crack is most likely to initiate and propagate in the Heat Affected Zone (HAZ) region, since local metallurgical changes may affect the local fatigue properties of the material, and defects are usually concentrated in this area.
- Residual stresses are set up in and near the weld due to the contraction of the weld metal during the cooling phase. These local residual stresses due to welding may reach yield stress magnitude, and affect the fatigue properties in a similar manner to externally imposed loads. Tensile residual stresses tend to reduce the fatigue strength, while compressive residual stresses may improve the fatigue strength. Attention to residual stresses is not only limited to the welding process, residual stresses may arise due to the restraints applied to the prefabricated units, the forcing of the prefabricated units during assembly, or uneven thermal expansion creating long range residual stresses acting over large areas. These long range residual stresses tend not to be relaxed by the occurrence of peak loads resulting in the so called shakedown process, or local treatment of the structural detail. However, they are generally of small magnitude compared to welding residual stresses.

2.3 Design stage fatigue strength improvement methods

2.3.1 It is clear that the most efficient method to improve the fatigue strength of welded structural details is at the design stage. To this effect, there are four factors which need to be specially considered to improve the fatigue strength of ship structural details as follows:

- Nominal stress level.
- Geometrical stress concentration due to the structural detail geometry.
- Weld geometry and construction tolerances.
- Residual stresses and construction procedure.

Each item outlined above is presented in the following Sections.

2.3.2 **Nominal stress level**. The most efficient way to improve fatigue strength is to increase the local scantling to reduce the nominal stress level, and hence the hot spot stress for a given structural detail. In general, structural details on higher tensile steel and aluminium require improvement in detail design over the mild steel and the base grade aluminium equivalent structural detail by virtue of the higher stress level and the constant fatigue strength for material of various yield strength. The advantages and disadvantages of this fatigue strength improvement method are summarised in Table 2.3.1.

Table 2.3.1 Nominal stress level

Advantages	Disadvantages
• Reduce stress level • Increase static strength • Potential decrease in number of structural components and/or complexity required over that for a structural detail in higher tensile strength material	• Increase structure weight

2.3.3 **Geometrical stress concentration**. The adoption of a good detail design configuration by the provision of soft connections reduces the geometrical stress concentration factor due to the geometrical discontinuity to a satisfactory level. Typical detail design improvements for the critical areas are provided in Chapters 4 and 5 of these Guidance Notes for steel/aluminium alloy and composite construction respectively. These detail design improvements have been developed from the consolidation of service experience and finite element analysis. The advantages and disadvantages of the subject fatigue improvement method are summarised in Table 2.3.2.

Table 2.3.2 Geometrical stress concentration

Advantages	Disadvantages
• Reduce hot spot stress level by reducing the local geometrical stress concentration • Most effective fatigue strength improvement technique • May provide additional structural redundancy	• May increase structural weight if additional pieces are required • Requires good workmanship where soft toe/heel are required

2.3.4 **Weld geometry and construction tolerances**. At the design stage, special attention may be given to achieving a favourable geometry and smooth transition at the weld toe, and minimising secondary stress concentration which may arise from the fit up and misalignment. Since the weld notch stress concentration is a direct function of the weld flank angle and the weld toe radius, critical structural details may be specified with an enhanced weld procedure and construction tolerances.

In view of the size and hull form of special service craft, additional considerations must, in general, be given to the accessibility for welding. This should include the selection of the depth, geometry and orientation of the stiffening members to provide the necessary access to carry out the required welding sequences, with the type and size of welding equipment available to the Builder.

The advantages and disadvantages of the subject fatigue improvement method are summarised in Table 2.3.3.

Table 2.3.3 Weld geometry and construction tolerances

Advantages	Disadvantages
• The improvement may be introduced at the design stage • The improvement is performed in the welding process itself • Subject to well defined inspection plan and hence higher reliability	• Improvement can be subject to large scatter if not controlled under QA survey conditions i.e., Fatigue Control Plan

2.3.5 **Residual stresses, and construction procedures**. The minimising of residual stresses through the adoption of appropriate welding procedures and sequences, the use of adequate unit size, and appropriate sequence of erection of the prefabrication unit do not constitute in themselves a fatigue strength improvement procedure. Nevertheless careful planning should be considered at the design stage to ensure that detrimental effects will not be introduced during the construction process.

Construction Tolerances and Defect Correction Procedures for Steel/Aluminium Construction

Section 1 Introduction

1.1 General

1.1.1 The fatigue life of structural details can be adversely affected by a variety of imperfections. The most common type of imperfections are:

(a) Misalignment of structural members, poor fit-up.
(b) Welding defects.
(c) Material defects.
(d) Poor manufacture and fabrication procedures resulting in stress concentrations.
(e) Unfairness of plating.

1.1.2 The actual influence on fatigue life will depend on the number, location and size of such imperfections.

1.1.3 Where design calculations highlight regions of stress concentration then experience clearly indicates that such regions will have a higher probability of failure during the life of the craft than surrounding structures. Hence in such locations there is a need to introduce standards that will reduce or eliminate the number or type of imperfections present.

1.1.4 Basic requirements concerning welding and structural details are given in Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively. The individual standards employed by Builders are normally based on individual national standards, e.g. British Standards, and these supplement the Rule requirements.

1.1.5 Construction and erection criteria in accordance with such standards must inevitably be taken into account in the fatigue life calculation for any structural detail. Whilst it may be anticipated that such criteria may, in general, in association with an acceptable detail arrangement, provide for adequate fatigue life, there may well be instances where there is a specific need to introduce construction tolerances that are more rigorous.

1.1.6 The LR Surveyors will be required to confirm that the work is carried out in accordance with the approved construction tolerances. Where the approved tolerances are exceeded then corrective action to the satisfaction of the Surveyor will be required. Details of the construction tolerances and defect correction procedures to be applied are indicated in Pt 3, Ch 1 of the Rules for Special Service Craft.

Section 2 Construction tolerances

2.1 General

2.1.1 Construction tolerances are to comply with Pt 3, Ch 1 of the Rules for Special Service Craft. The additional guidance given in this Chapter should also be complied with where practicable.

2.2 Defects in steel/aluminium products

2.2.1 Where defects are found in materials after delivery to the Builder, any rectification should be agreed with the LR Surveyor and should generally be in accordance with Ch 3,1.10 or Ch 8,1.10 of the Rules for Materials and aluminium respectively.

2.2.2 If lamination is found during plate preparation the extent of the lamination should be ascertained by ultrasonic examination. Renewal of the affected material is normally recommended.

2.3 Construction standards

2.3.1 Construction standards (including preparation of material, joint alignment, type of welded joint, fit-up prior to welding, steps to be taken for rectification of defects, etc.) are to be agreed between LR and the Builder. Such standards will be recorded and kept on file by LR. In a number of countries national standards exist in respect of the acceptable shipbuilding standards.

2.3.2 In shipyards certified under the LR Quality Assurance Scheme, the standards will have received general approval as part of the certification procedures and their application to particular craft will be included in the quality plan submitted to LR for approval.

2.3.3 In considering critical locations and their construction standards it also has to be borne in mind that craft construction is a traditional process with alignment standards based on heel lines. In addition, therefore, to establishing the more critical joints in terms of fatigue life, consideration of the thicknesses to be employed in these joints should be a fundamental factor. If the heel line principle is maintained at the toes of, for example, primary member end brackets, where increased thicknesses are employed, the arrangements will in reality, be out of line, even though perfect alignment is attained to the standard, *see* Fig. 3.2.1(a). It is therefore recommended, particularly for aluminium, that a median line principle is employed at this local area so that an improved alignment can be more easily attained. From LR's point of view the various thicknesses of plating at structural joints, particularly the higher stress joints, is an important consideration. In this respect the gradient of load through the through-thickness loaded plate should be controlled to a maximum of one in three, *see* Fig. 3.2.1(b).

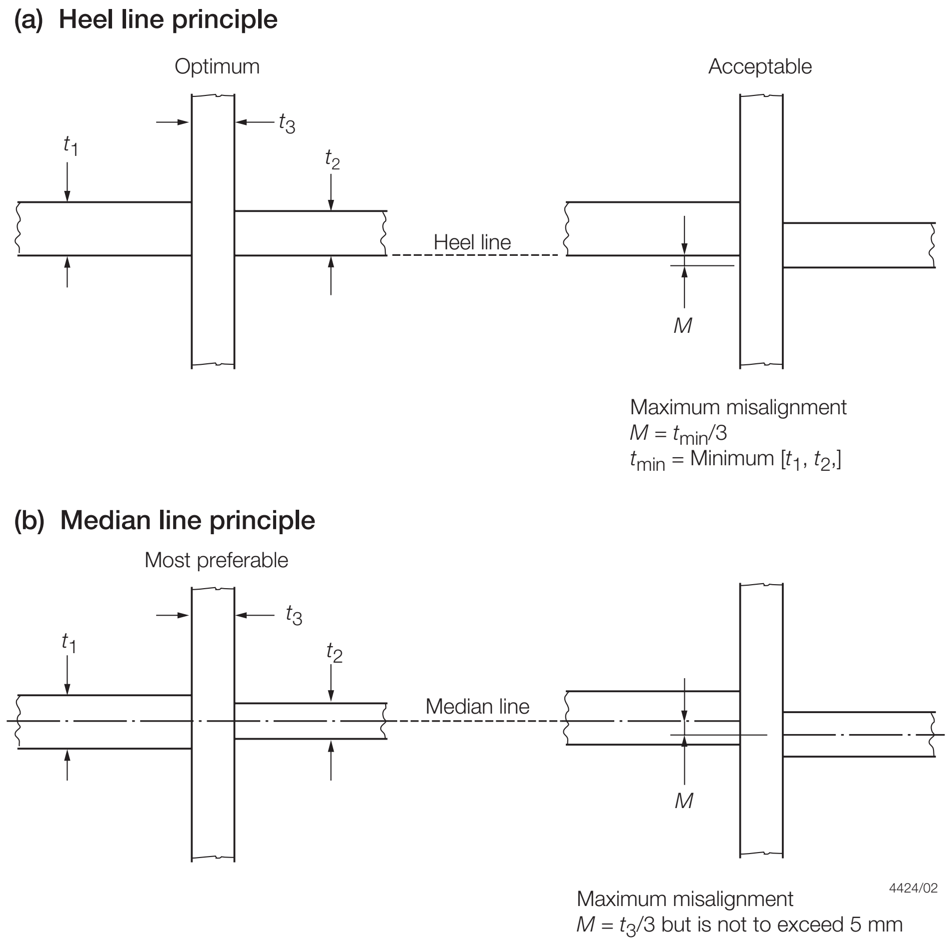


Fig. 3.2.1 Recommended alignment of primary members

2.3.4 In addition to cruciform joint misalignment, the alignment of secondary stiffening and associated brackets is also important. Recommendations are made in Fig. 3.2.1 and Fig. 3.2.2. Where centreline alignment is recommended the tolerance guideline in Fig. 3.2.2 should be followed.

2.3.5 Whenever possible the plate thicknesses, t_1 and t_2, (*see* Fig. 3.2.1) should be kept as close as possible in order to minimise the potential difficulties associated with a median line alignment.

2.4 Prefabrication

2.4.1 Throughout the preparation of material and assembly of prefabrication units, the workmanship is to be inspected in order to ensure that correct procedures are being followed. By attention in the early stages of construction, undesirable procedures and faulty workmanship can be avoided, or their consequences minimised. When the existence of such defects is noticed prompt and suitable measures are to be taken for rectification.

2.4.2 Examination of structure will normally be carried out during the prefabrication of units, and liaison between the LR Surveyor and the Builder's drawing offices and quality control departments will ensure that attention is also given to details which may not have been included on approved plans (air and drainage holes, etc.) during early material preparation stages.

2.4.3 It should be borne in mind that visual examination of welds and plating of a finished structure does not necessarily ensure a complete and satisfactory survey. Procedures are to be such as to ensure that adequate inspection is made of joint preparation before welding. Attention is drawn to the guidance on welding and structural details in Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium alloy craft respectively. Regular examination by the LR Surveyor, in conjunction with the Builder, of non-destructive examination and other Quality records provides a check on the quality of welding operations and any decline in standards should be investigated, including additional tests as considered desirable.

2.4.4 It is essential that a good standard of cleaning be achieved for these inspections. Special attention, as indicated in Pt 7, Ch 2,3.11.5 of the Rules for Special Service Craft, are to be applied for aluminium. For steel structures welding slag should be removed and rusting of weld deposits should be removed by wire brushing.

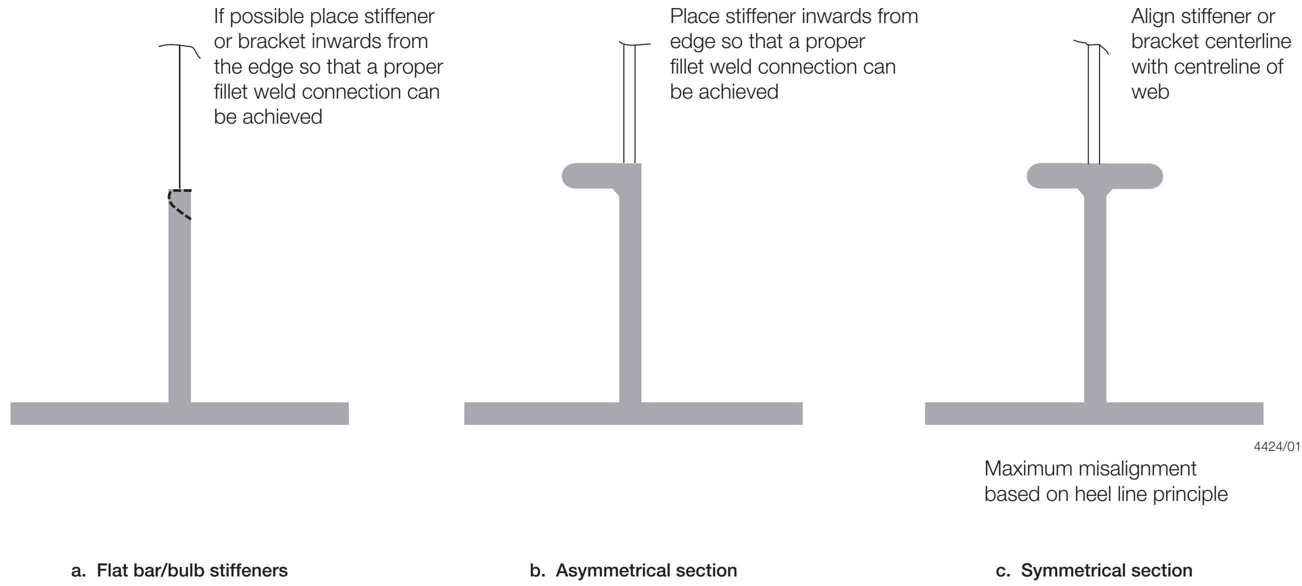


Fig. 3.2.2 Recommended alignment of secondary stiffening members

2.5 Assembly of units

2.5.1 The Builder and the LR Surveyors must ensure by regular and systematic examination that the control exercised up to the stage of block assembly is maintained by the efficient erection of blocks at the berth. It is particularly necessary at this point to ensure that fit-up, alignment, adjustment and welding of blocks is in accordance with the approved plans and building standards. Attention is to be given to the sequence of erection and of welding. Particular attention should be given to length allowance for unwelded stiffening member alignment.

2.5.2 With the assembly of large blocks careful attention should be paid to the areas in way of lifting lugs. It is not unusual to find small cracks in the vicinity of the weld area after removal of lugs. Where lugs are removed the dressing of the plate must be thorough and examination by means of crack detection of the finished surface is good practice. Repair of any cracks found must be carried out by skilled welders under strict control.

2.5.3 Any unusual incidents during construction, such as fracturing of plates, should be noted and brought to the attention of the LR Surveyor. It will be necessary to have full information on the circumstances affecting such cases, such as position and extent of the fracture relative to adjacent structure and welds, atmospheric temperature, details of joints, precise stage and sequence of welding, type of electrode filler wire used, whether or not pre-heating was used, grades of steel or aluminium alloy involved and any other factors considered to have had a possible influence. Test details of affected plates and proposals for remedial measures should also be made available. Where doubt exists in establishing the source of such incidents, the assistance of LR's staff at Headquarters, should be sought.

■ *Section 3* **Defect correction procedures**

3.1 Inspection and testing

3.1.1 The fabrication specification should state the extent of visual inspection and non-destructive examination along with details of the techniques and the appropriate acceptance criteria.

3.1.2 All non-destructive examination should be in accordance with written procedures. (*See also* Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft for steel and aluminium craft respectively).

3.1.3 Quality control levels for weld flaws found by radiographs, ultrasonic testing, magnetic particle and dye penetrant inspection, as appropriate, are to be approved by LR and shall be imposed during fabrication as a means of quality control.

3.1.4 Welded joints critical to the integrity of the structure should be subjected to radiographic examination and/or, where applicable, surface examination during construction. This non-destructive examination should be carried out prior to delivery, after the completion of welding and prior to any coating which would adversely effect the type of non-destructive examination being undertaken. Any repairs resulting from the testing are be re-examined.

3.1.5 Any necessary repairs and corrective actions are to be carried out to the satisfaction of the LR Surveyor and in accordance with an agreed procedure.

Detail Design Improvement for Steel/Aluminium Construction

Section

■ *Section 1* Identification of critical areas

1.1 General

1.1.1 LR has applied direct calculation procedures in the structural appraisal and approval of new buildings and in various investigations on special service craft of both steel and aluminium alloy construction. Through these procedures and the wealth of information collected on the LR fleet database, a number of locations have been identified where good design, workmanship and alignment during construction are particularly important. These are usually locations where high stress variations can be experienced during the lifetime of the craft. These are referred to to as **critical locations** and are highlighted in this Chapter.

1.1.2 This Chapter identifies the **critical areas** within various structural elements of the hull structure and transverse bulkheads.

1.1.3 In Section 2 the structural **detail design improvements** that can be applied to increase the fatigue life of the structural components are provided. These detail improvements are intended to give the designer guidance for meeting the design criteria for structural detail components.

1.1.4 The application of 2 and 3-dimensional finite element analyses techniques to the hull structure enables the global and local capabilities of the hull structure to withstand static and dynamic loadings to be assessed. Such analyses will enable those high stress locations and joints within the craft to be readily identified. Such locations will then, by their very nature, be at risk to fatigue damage unless appropriate measures are taken at the design stage and subsequently during construction.

1.1.5 Extensive ‘in service’ experience of the performance of existing craft structures, already provide an awareness of those critical locations which merit particular attention either due to stress or alignment difficulties.

1.2 Critical areas

1.2.1 Stress concentrations occur in both the primary and secondary structures of all craft and are identified during the design process by such means as finite element calculations. The designer will modify the detail to alleviate the stress concentration either by redesign or increase in scantlings. However, even after modification that area will still, in general, be exposed throughout the life of the craft to stresses higher than in surrounding areas.

1.2.2 At the design appraisal stage, a plan of the structure should, where appropriate, be prepared indicating by the Builder or designer these regions, and consideration can then be given, by the production team, into the appropriate methods of construction and the tolerances to be applied in order to remain within the assigned design parameters.

1.3 Misalignment during construction

1.3.1 The very nature of steel/aluminium construction requires the assembly of a multitude of structural components into blocks within an assembly shop and then the erection of these blocks within a building dock or on a building berth. The welded interface between structural components in sub-assembly areas can be reasonably controlled; however, the welded connections between large prefabricated blocks in the building dock or on the building berth cannot be so easily controlled due to the sheer size of the blocks being handled.

1.3.2 The most critical type of joint is the welded cruciform joint where it is subjected to high magnitudes of tensile stress normal to the table member of the joint.
The double bottom construction lends itself to the block construction. The interfaces between these blocks and those formed by the primary transverse structure may lie in areas of high stress. Critical cruciform joints are also found within the prefabricated blocks and also require close attention to alignment, but this is more easily achieved.

1.3.3 It can readily be seen that the combination of stress concentration and misalignment is to be avoided if the fatigue strength is to be satisfactory during the service life of the craft.

1.4 Fatigue considerations

1.4.1 The bottom shell area of high speed craft is subjected to the highest cyclic loading throughout the life of such craft.

1.4.2 The fatigue fractures in bottom longitudinal end-connections of higher tensile steel and aluminium alloy has been well documented, and constructional details in way of these connections, designed to increase fatigue life, are now incorporated by many Builders as standard. It is, therefore, important that due consideration be given to this detail at the design stage to reduce the risk of fatigue cracking during service.

1.4.3 Detailed recommendations are given herein for the critical areas, *see* Section 2.

Section 2
Structural details

2.1 Detail design improvement

2.1.1 For the purposes of these Guidance Notes, structural locations have been divided into three separate groups, with a series of examples of critical structural areas together with alternative associated detail design improvements.

2.1.2 A summary of the data presented is given in Table 4.2.1 whilst the full details are given in Figs. 1 to 29 as contained in this Section.

2.1.3 Generally, where alternative structural detail design improvements are provided, the details shown will provide improved fatigue strength.

2.1.4 Where asymmetrical sections are shown, the same requirements apply to bulb plate stiffeners and flat bars.

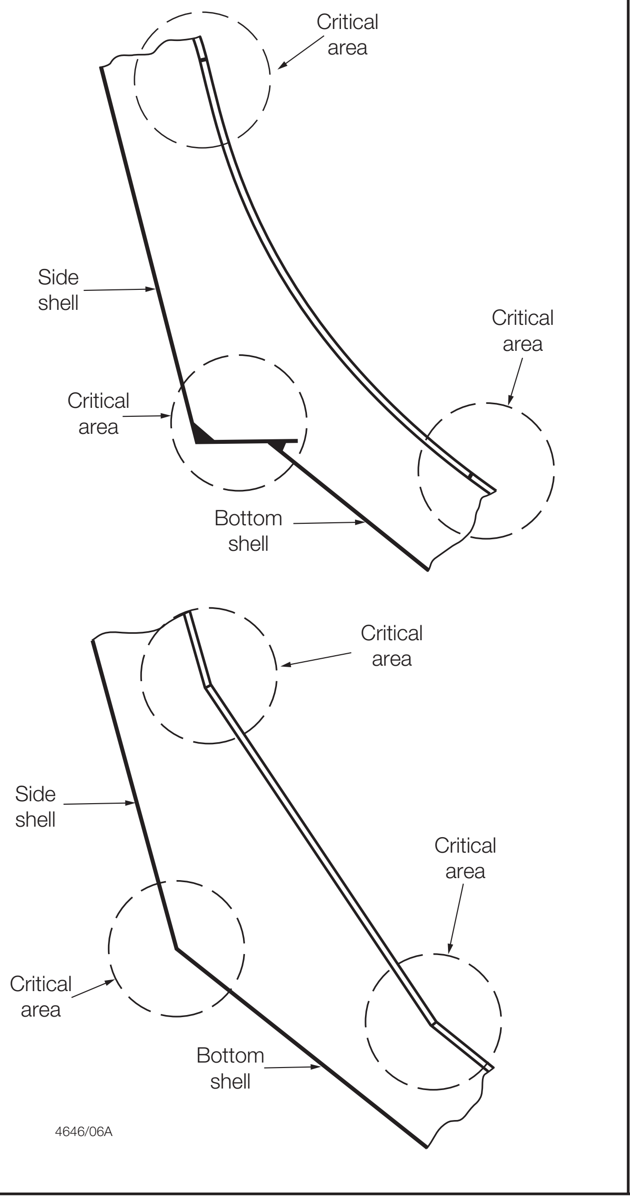
Table 4.2.1

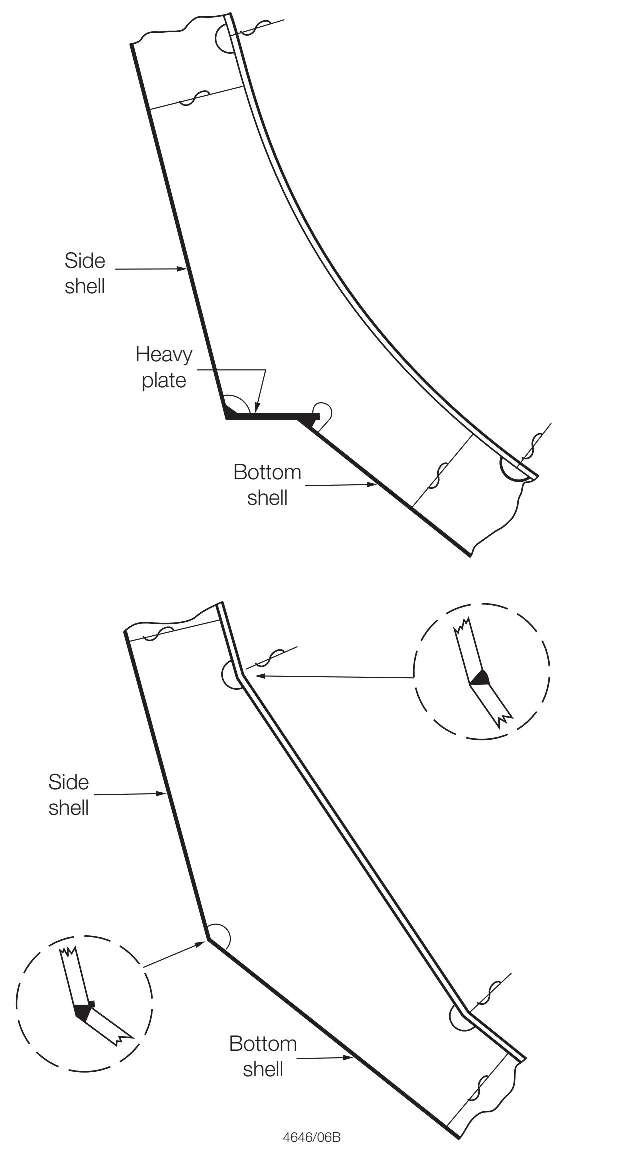
Group	Application	Area	Item	Fig. No
	High speed craft			
1		Hull structure	Chine to frame connection	1
		Hull structure	Chine and chine bar details (1)	2
		Hull structure	Chine and chine bar details (2)	3
		Hull internal structure	Frame to beam connection (radiused)	4
		Hull internal structure	Frame to beam connection (continuous bracket)	5
		Hull internal structure	Lug connections between secondary stiffeners and primary stiffener webs (1)	6
		Hull internal structure	Lug connections between secondary stiffeners and primary stiffener webs (2)	7
		Watertight/oiltight bulkheads	Shell longitudinals collared, brackets aligned	8
		Watertight/oiltight bulkheads	Shell longitudinal (fitted brackets)	9
		Watertight/oiltight bulkheads with boundary bar	Shell longitudinal (fitted brackets)	10
		Watertight/oiltight bulkheads	Collar inserts in way of secondary stiffening members	11
		Watertight/oiltight bulkheads	Collar inserts in way of primary stiffening members	12
		Cross-deck structure, multi-hulls	Inner side web frame to deck transverse connection	13
		Cross-deck structure	Deck transverse to watertight bulkhead connection	14
		Multi-hull structure	Cross-deck beam to bulkhead connection	15
	Low speed craft			
2		Hull internal structure	Floor to frame connection (bracketed)	16
		Hull internal structure	Frame to beam connection	17
		Watertight/oiltight bulkheads with boundary bar	Shell longitudinals (lapped brackets)	18
		Watertight/oiltight bulkheads	Shell longitudinals (lapped brackets)	19
		Watertight/oiltight bulkheads	Shell longitudinals collared, brackets lapped	20
		Cross-deck structure, multi-hulls	Connection between cross-deck beams and side hulls	21
	General detail			
3		Cross-deck structure, multi-hulls	Connection between cross-deck beams and side hulls	22
		Hull centreline structure	Bar and plate keels	23
		Hull centreline structure	Bar keels	24
		Hull centreline structure	Fabricated plate keel/skeg	25
		Hull centreline structure	Round bar and flat bar stems	26
		Hull centreline structure	Fabricated and plate stems	27
		Hull internal structure	Floors to frame connection (radiused)	28
		Hull internal structure	Web frame to tank boundary connection	29

AREA:	Hull structure
ITEM:	Chine to frame connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





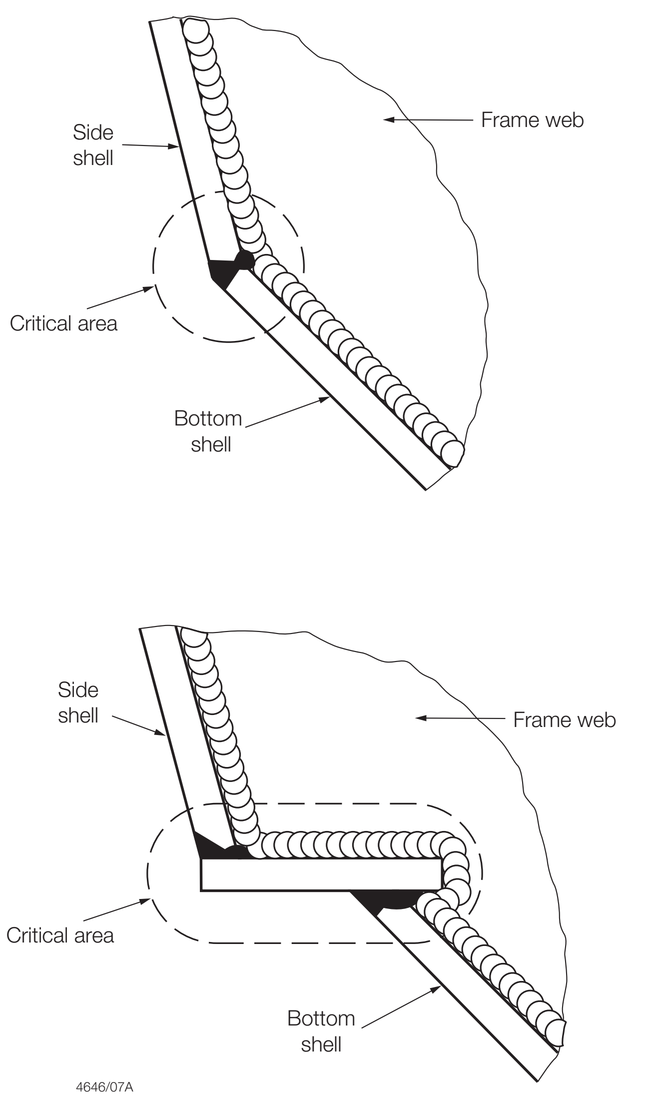
NOTES

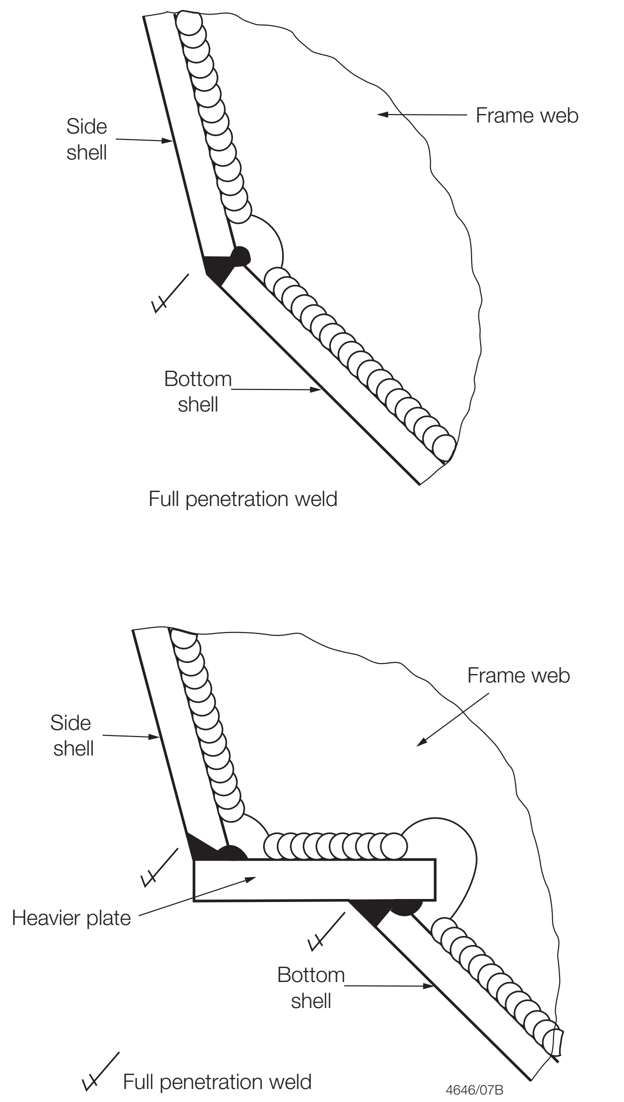
Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between chine bars and shell plating is to be full penetration type. Butts in web plating and face flats are to be staggered.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	1

AREA:	Hull structure
ITEM:	Chine and chine bar details (1)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of shell plating and between chine bar and shell plating is to be full penetration type. Welds are to be returned around scallops.

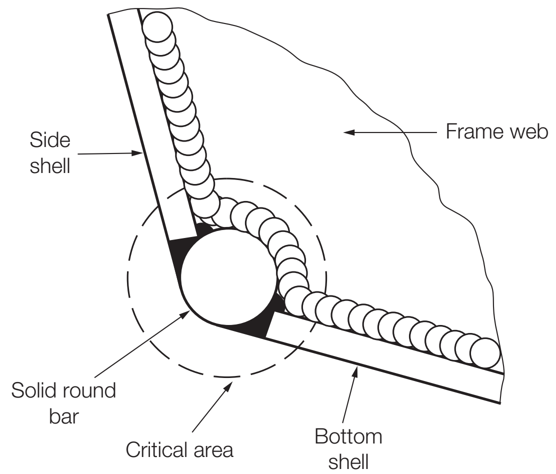
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	2

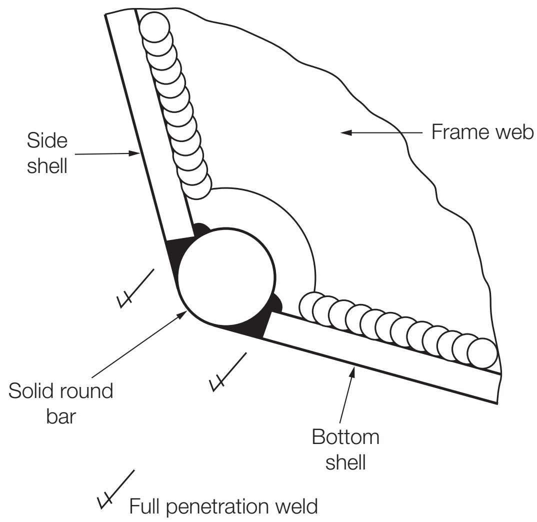
Detail Design Improvement for Steel/Aluminium Construction

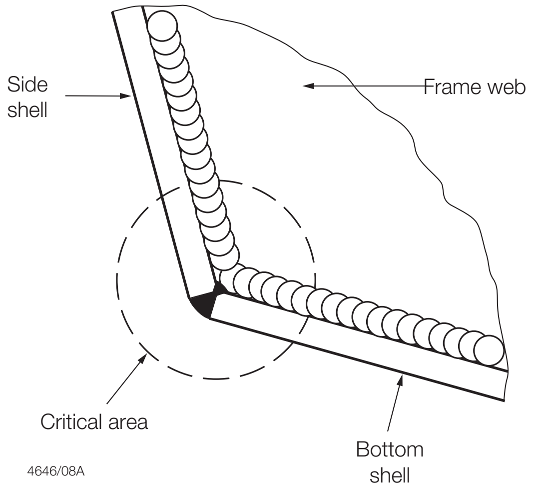
AREA: Hull structure

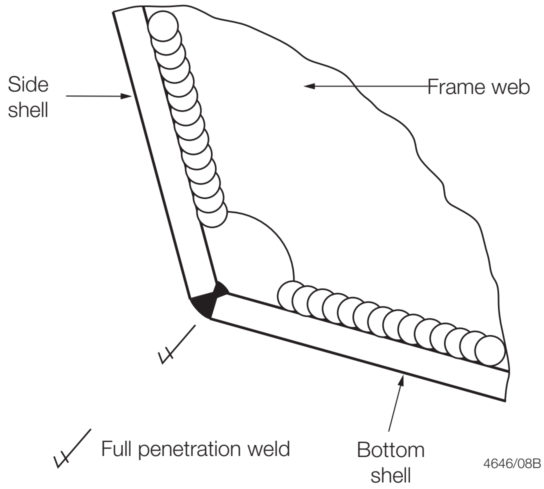
ITEM: Chine and chine bar details (2)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







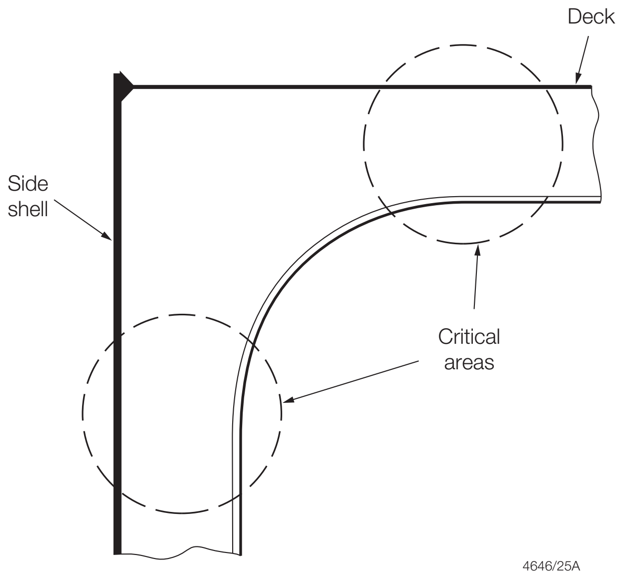
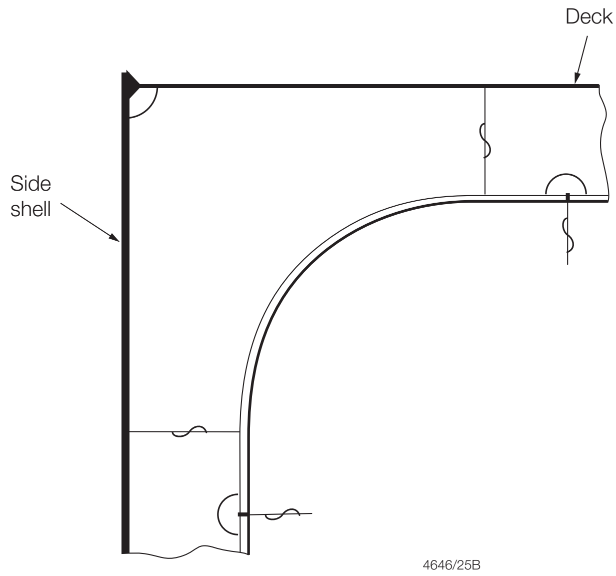


NOTES

Failure Mechanism	Fatigue fractures from areas of tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of shell plating and between chine bar and shell plating is to be full penetration type. Welds to be returned around scallops.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 3

AREA:	Hull internal structure	Lloyd's Register
ITEM:	Frame to beam connection (radiused)	

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

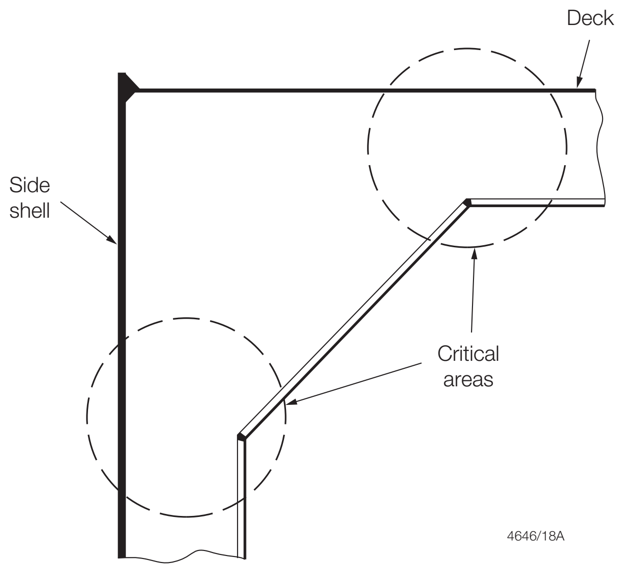
NOTES

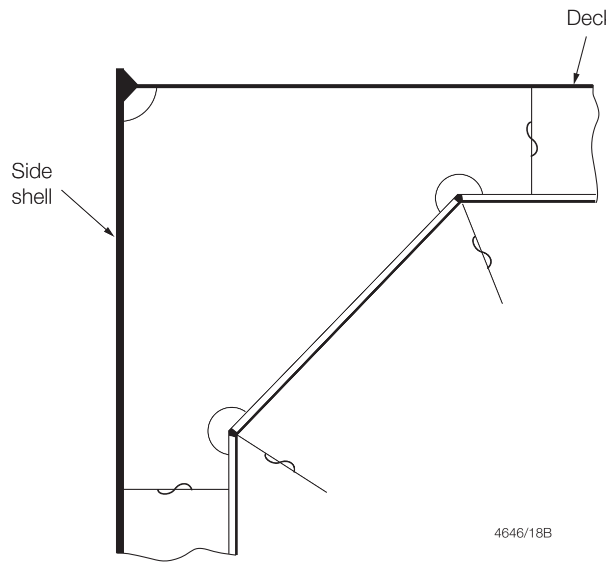
Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs to be accurately aligned. Butts in webs are to be staggered from the butts in face flats. All welds to be returned around scallops.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 4

AREA:	Hull internal structure
ITEM:	Frame to beam connection (continuous bracket)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



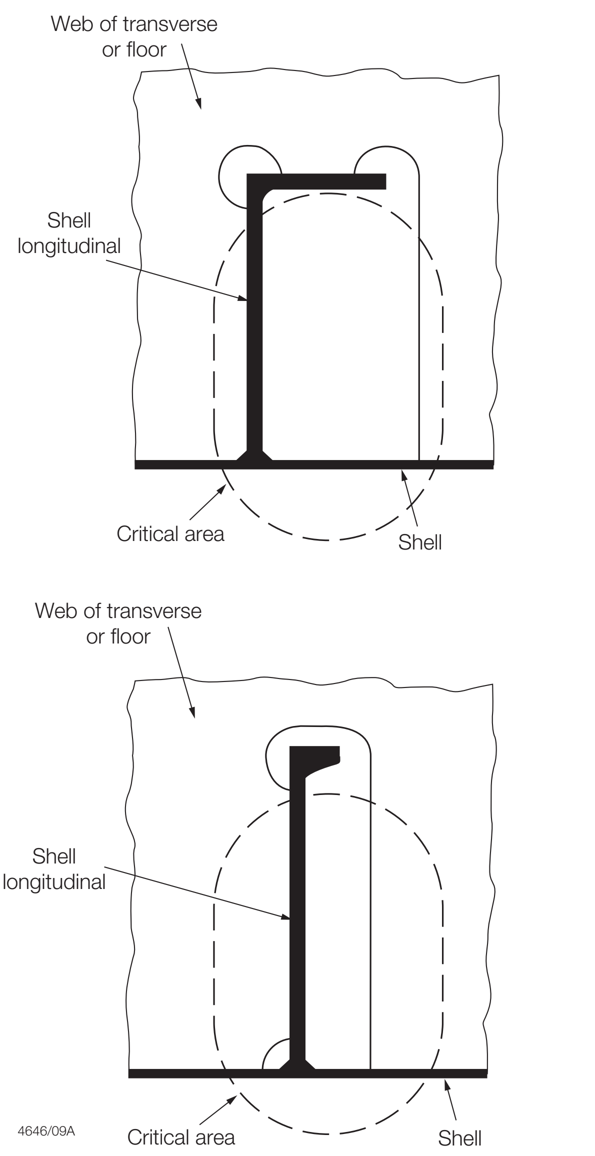
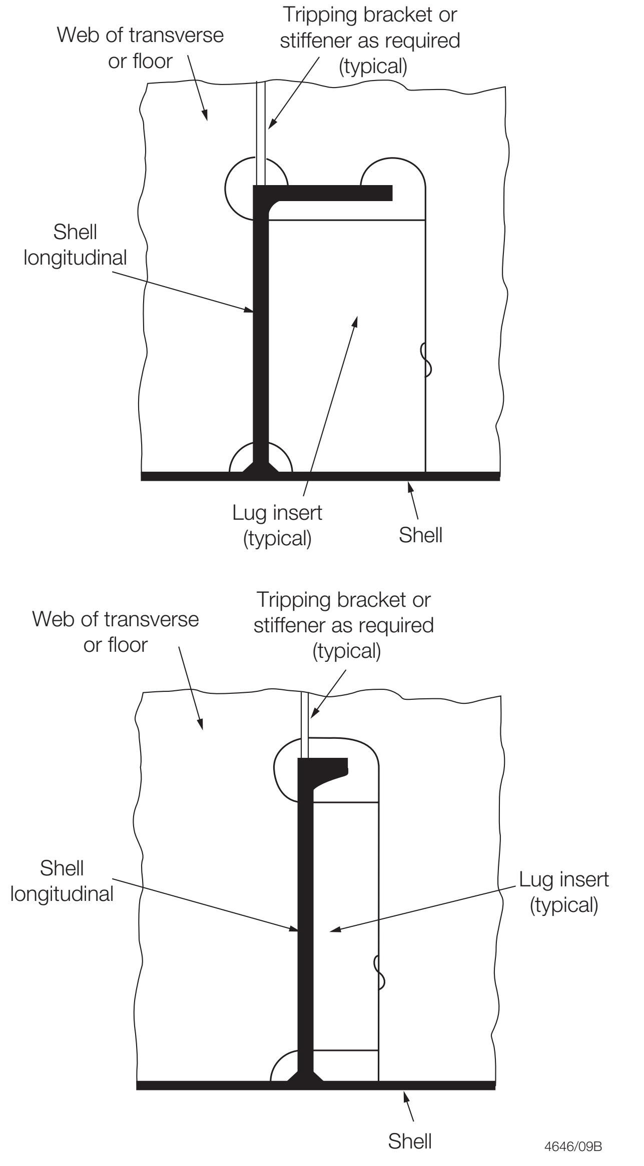


NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs to be carefully aligned. Butts in webs are to be staggered from the butts in face flats. All welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	5

AREA:	Hull internal structure	Lloyd's Register
ITEM:	Lug connections between secondary stiffeners and primary stiffener webs (1)	

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Fatigue cracking of shell plate in way of hardspot, buckling and shear failure of the web of the primary member.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of lugs is to be double continuous. Welds to be returned around scallops. Lug inserts to align with primary stiffener web plating or floor.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	6

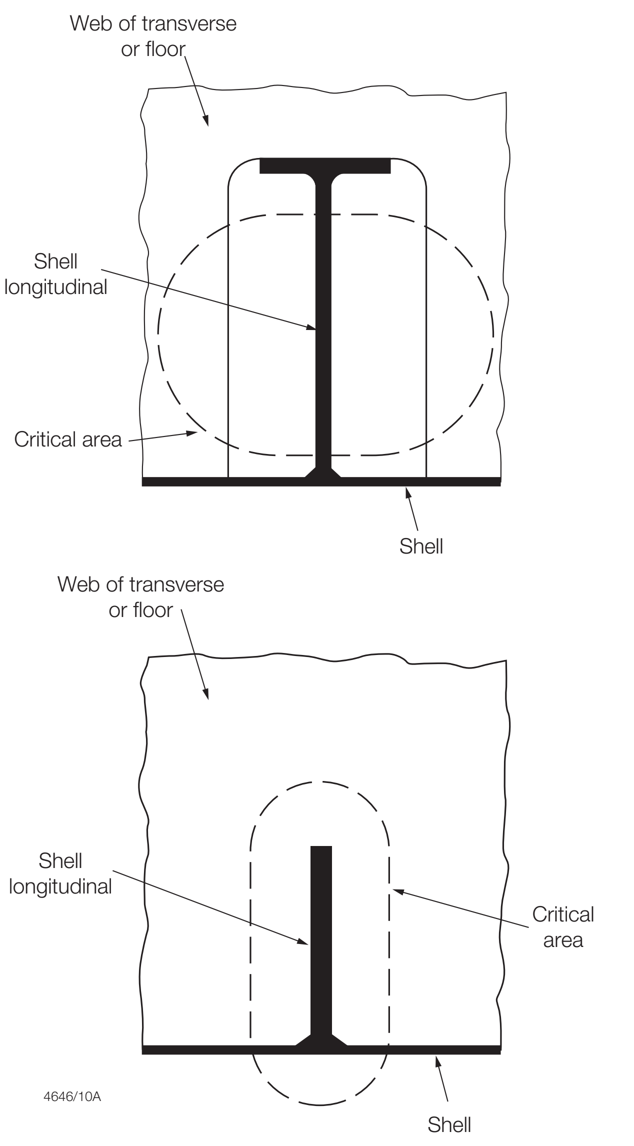
Detail Design Improvement for Steel/Aluminium Construction

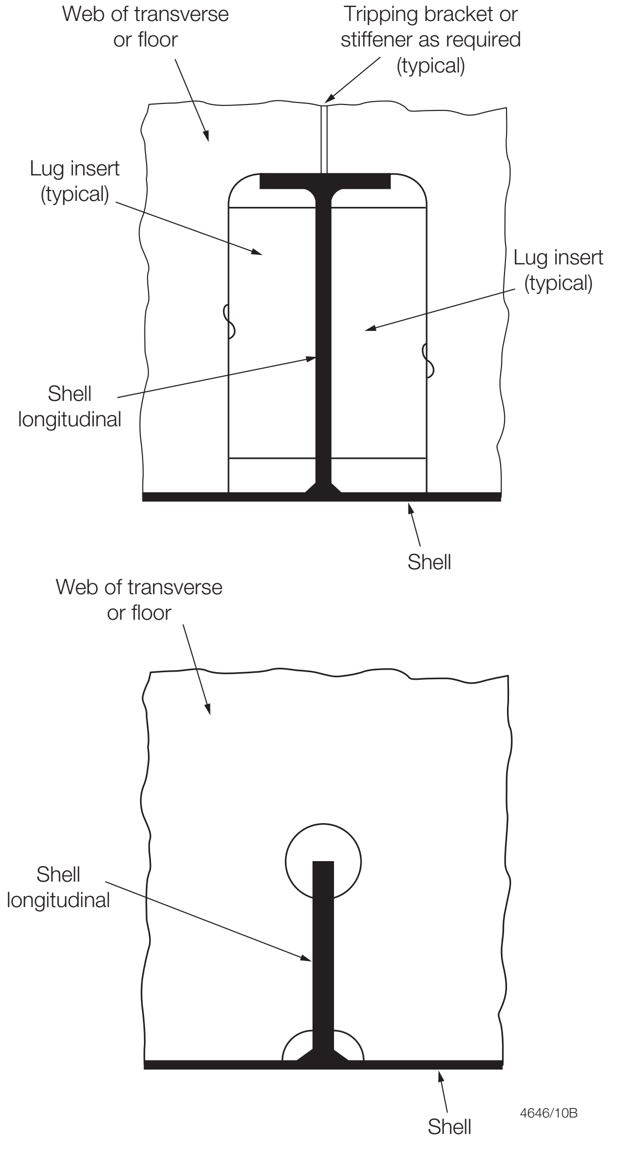
AREA: Hull internal structure

ITEM: Lug connections between secondary stiffeners and primary stiffener webs (2)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

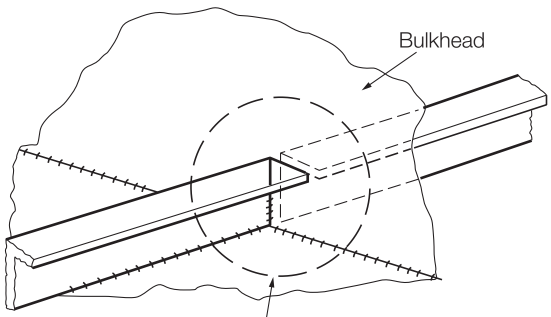
Failure Mechanism	Fatigue cracking of shell plate in way of hardspot, buckling and shear failure of the web of the primary member.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of lugs is to be double continuous. Welds to be returned around scallops. Lug inserts to align with primary stiffener web plating or floor.

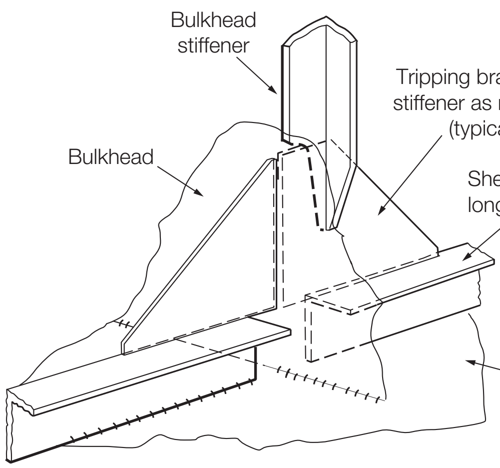
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	7

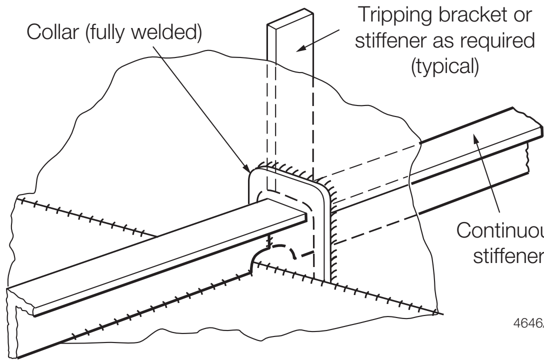
AREA:	Watertight/oiltight bulkheads
ITEM:	Shell longitudinals collared, brackets aligned

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







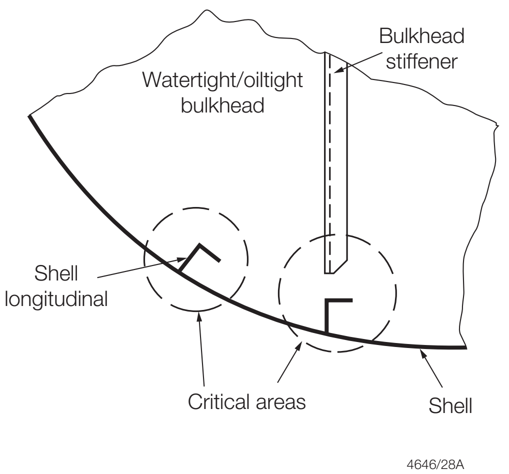
NOTES

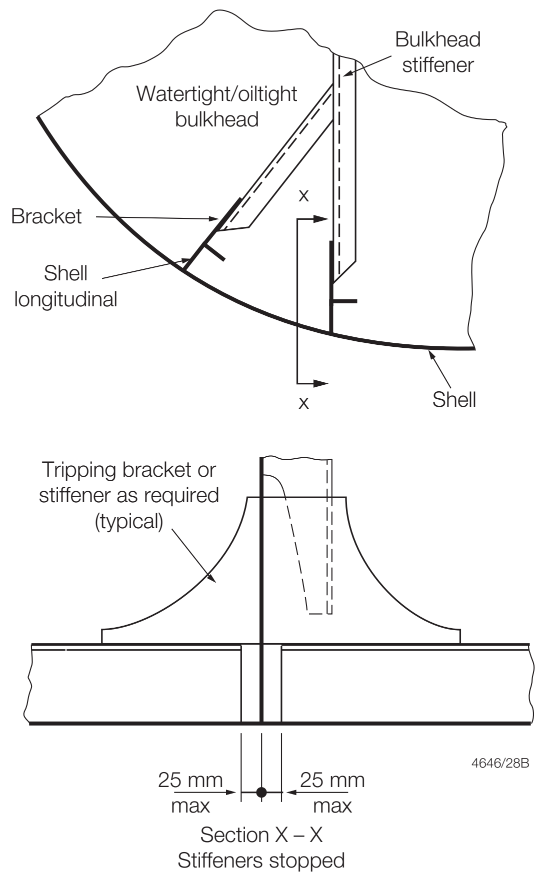
Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of collar and stiffener end connections is to be double continuous type. Welds to be returned around scallops.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	8

AREA:	Watertight/oiltight bulkheads
ITEM:	Shell longitudinals (fitted brackets)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





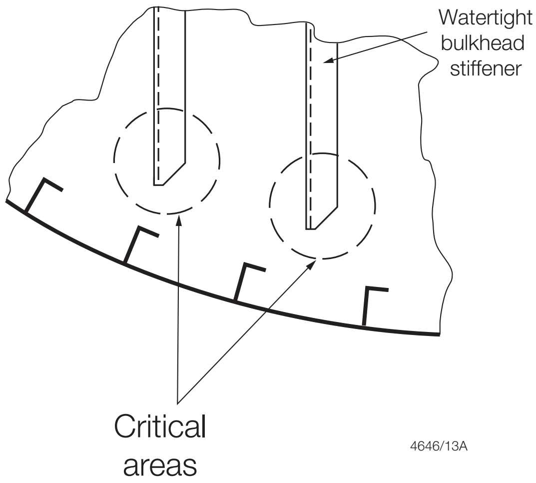
NOTES

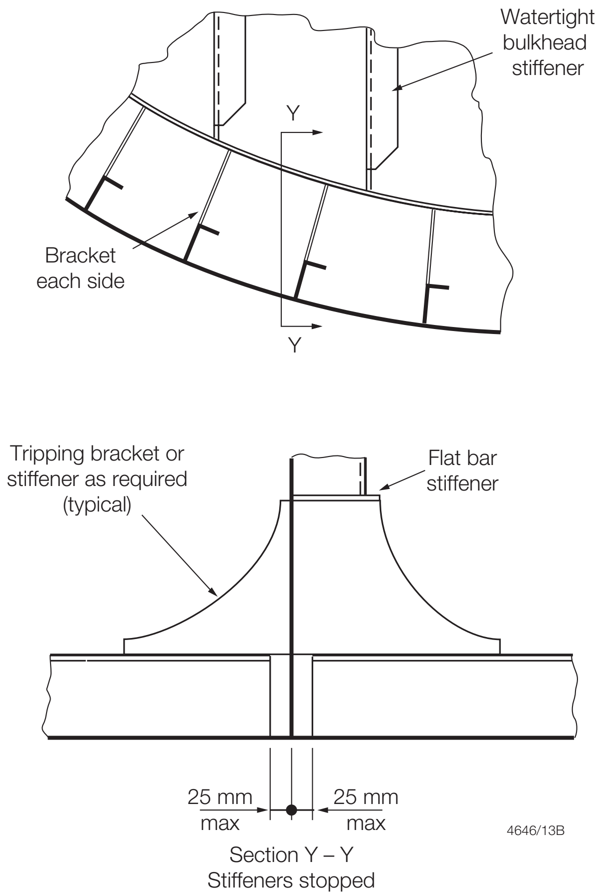
Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead plating and with the webs of the longitudinal stiffeners. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 9

AREA:	Watertight/oiltight bulkheads with boundary bar
ITEM:	Shell longitudinals (fitted brackets)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

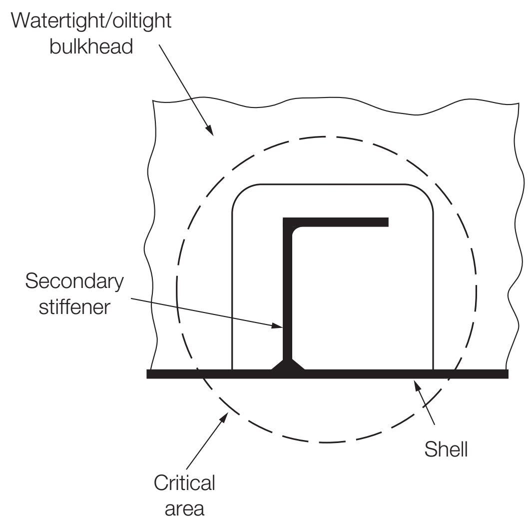
Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead plating and with the webs of the longitudinal stiffeners. All welding in way of brackets and stiffener end connections is to be double continuous type.

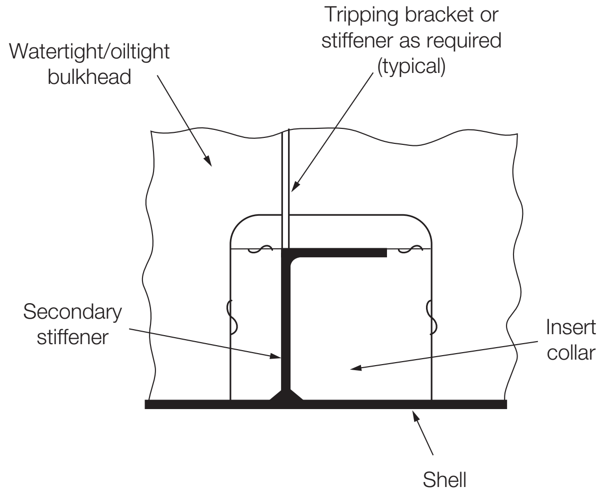
GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 10

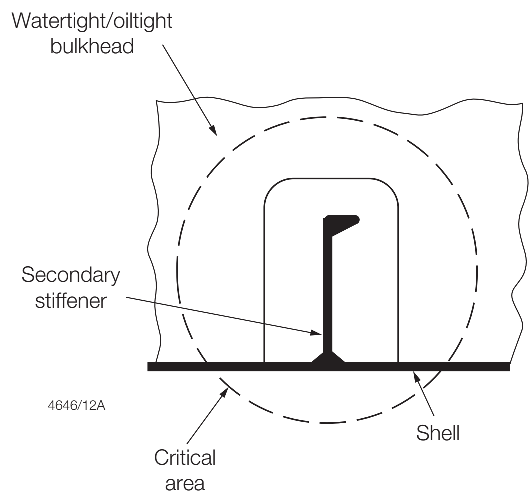
Detail Design Improvement for Steel/Aluminium Construction

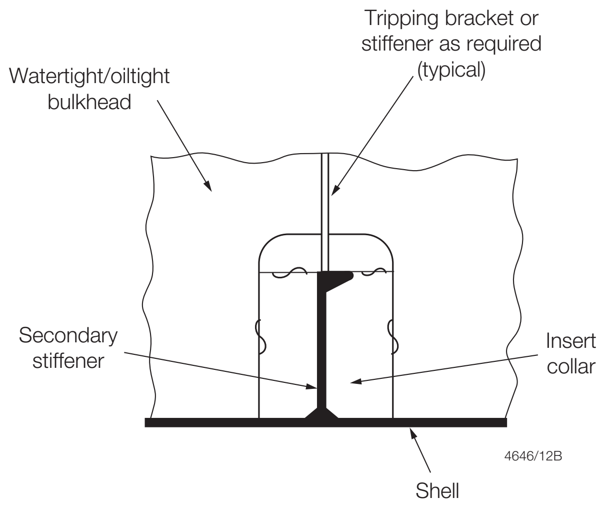
AREA:	Watertight/oiltight bulkheads	Lloyd's Register
ITEM:	Collar inserts in way of secondary stiffening members	

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

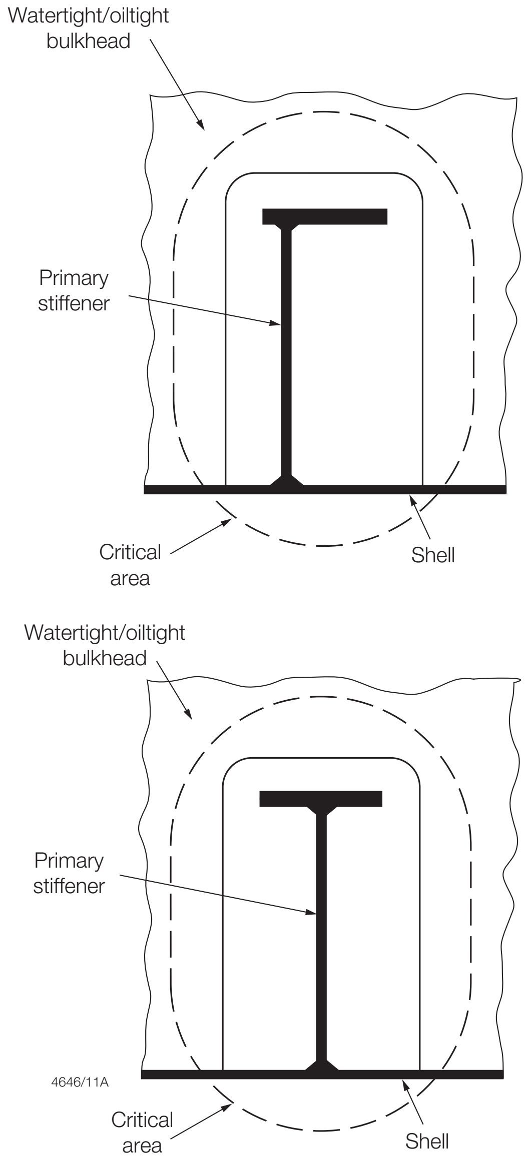
Failure Mechanism	Fatigue fractures and leakage.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Inserts to align with watertight/oiltight bulkhead plating. All welding in way of collar inserts and stiffener end connections is to be double continuous type.

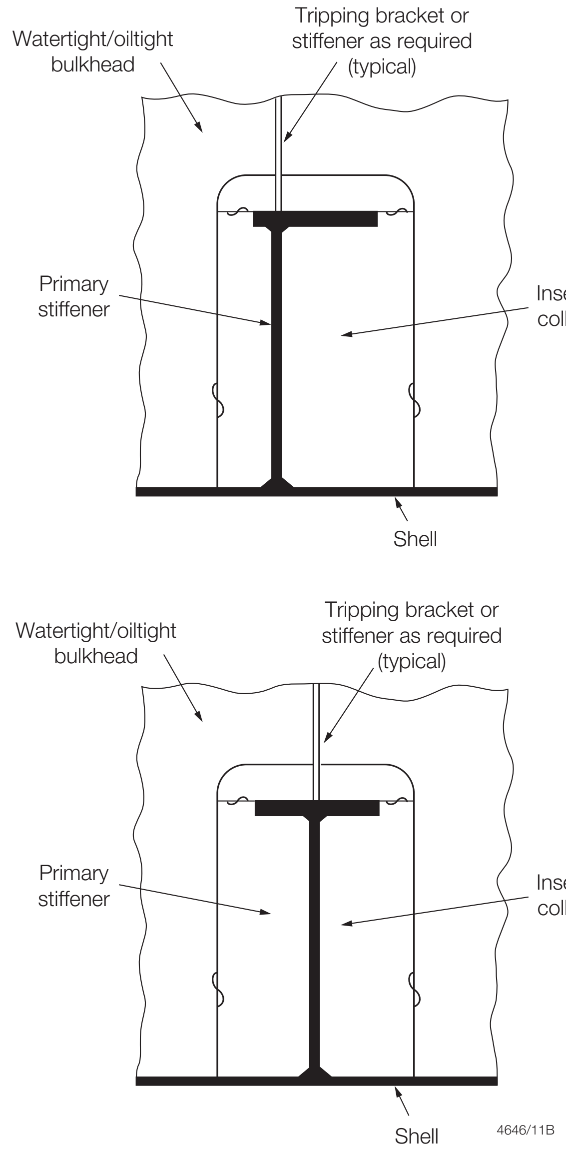
GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 11

Detail Design Improvement for Steel/Aluminium Construction

AREA:	Watertight/oiltight bulkheads
ITEM:	Collar inserts in way of primary stiffening members

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





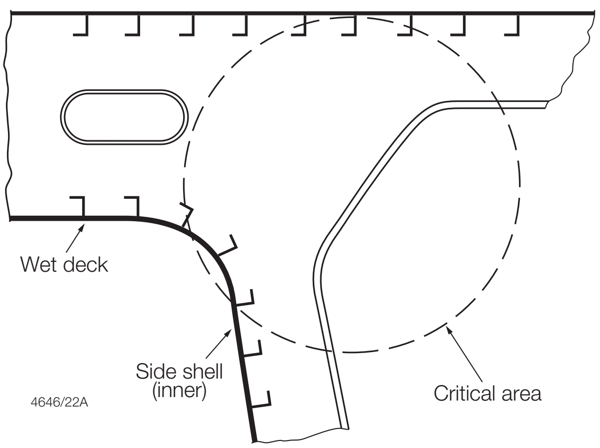
NOTES

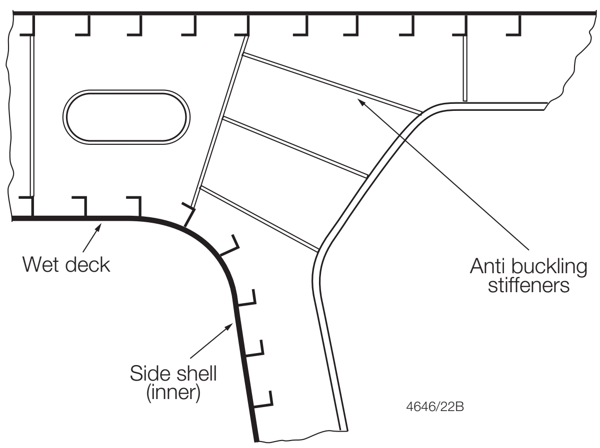
Failure Mechanism	Fatigue fractures and leakage.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Inserts to align with watertight/oiltight bulkhead plating. All welding in way of collar inserts and stiffener end connections is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	12

AREA:	Cross-deck structure, multi-hulls
ITEM:	Inner side web frame to deck transverse connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of deep webs.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	13

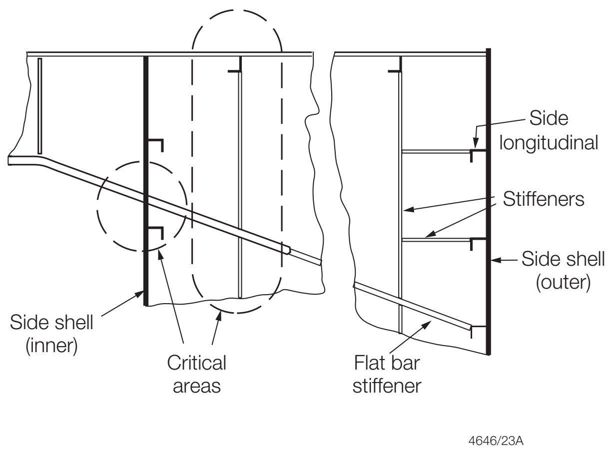
Detail Design Improvement for Steel/Aluminium Construction

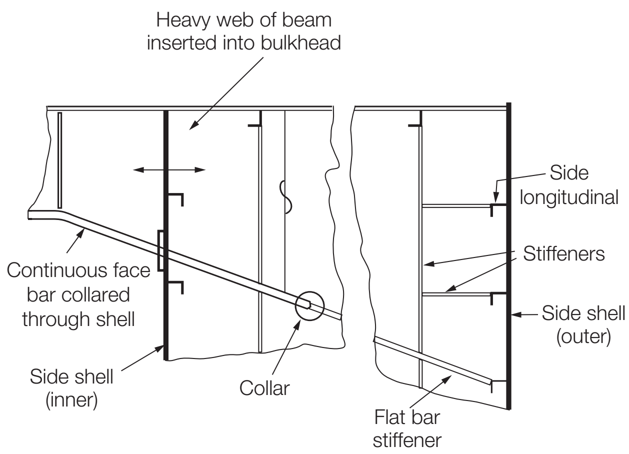
AREA: Cross-deck structure

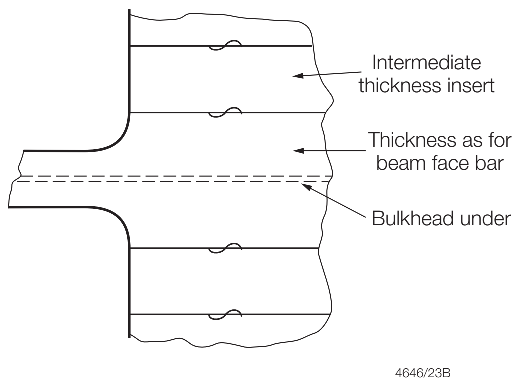
ITEM: Deck transverse to watertight bulkhead connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT







Plan view

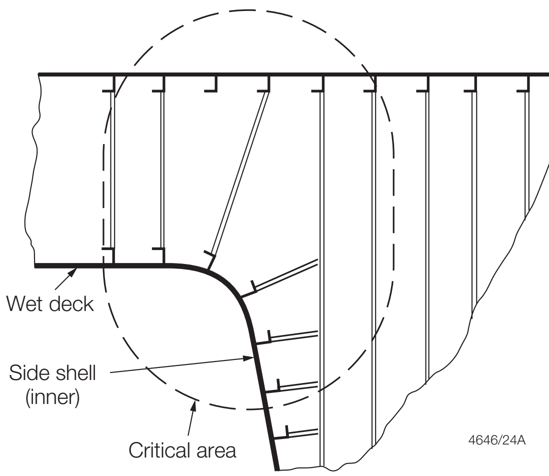
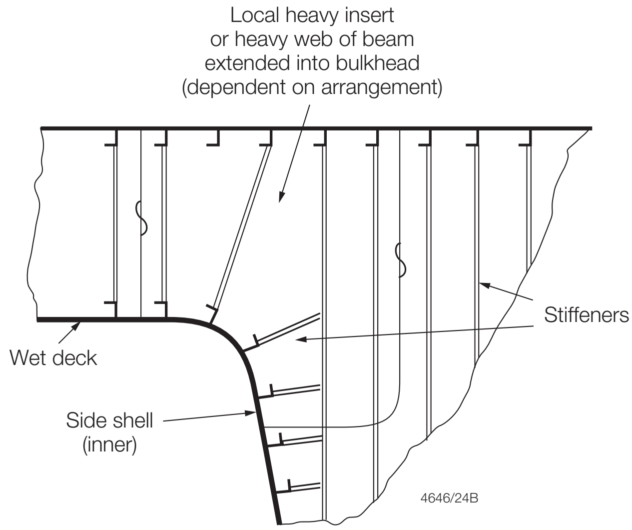
NOTES

Failure Mechanism	Failure fractures in areas of high stress, cracking due to both stress concentrations and tri-axial stress.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welds in way of shell penetration are to be full penetration type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	14

AREA: Multi-hull structure

ITEM: Cross-deck beam to bulkhead connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism — Buckling of deep webs and bulkhead in way of connection.

Building Tolerance — To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.

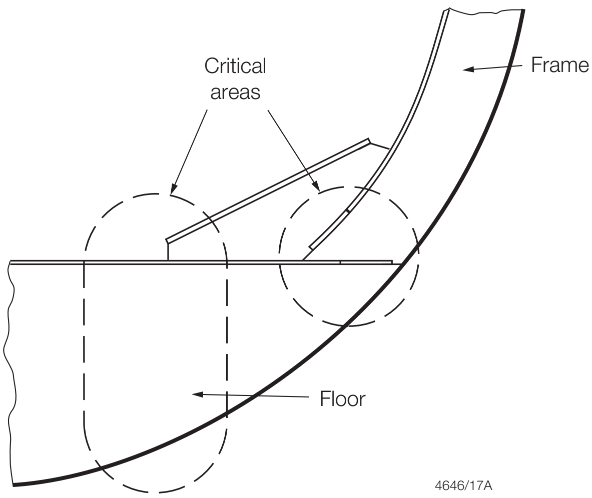
Welding Requirements — To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of deep transverses are to be accurately aligned with the bulkhead plating. All welding in way of end connection is to be double continuous type.

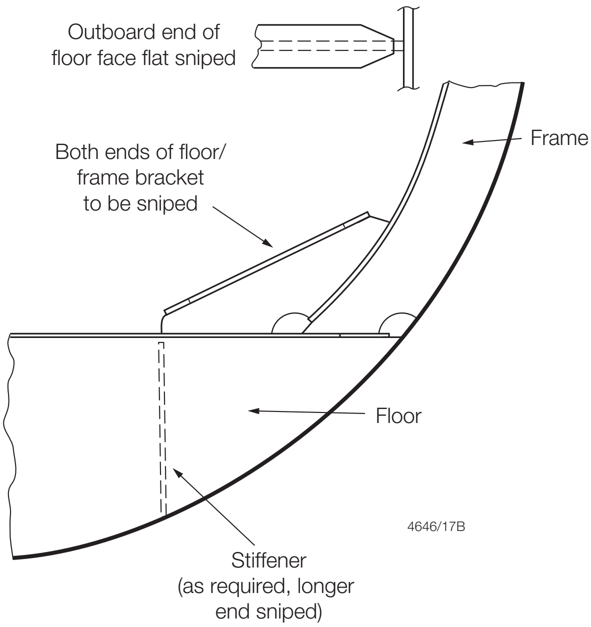
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	STEEL/ALUMINIUM CONSTRUCTION	15

AREA:	Hull internal structure
ITEM:	Floor to frame connection (bracketed)

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of floor under bracket toe. Fracturing of frame and floor structure in way of end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of brackets and end connections is to be double continuous type. All welds to be returned around scallops. Webs of frames to be accurately aligned with floor plating.

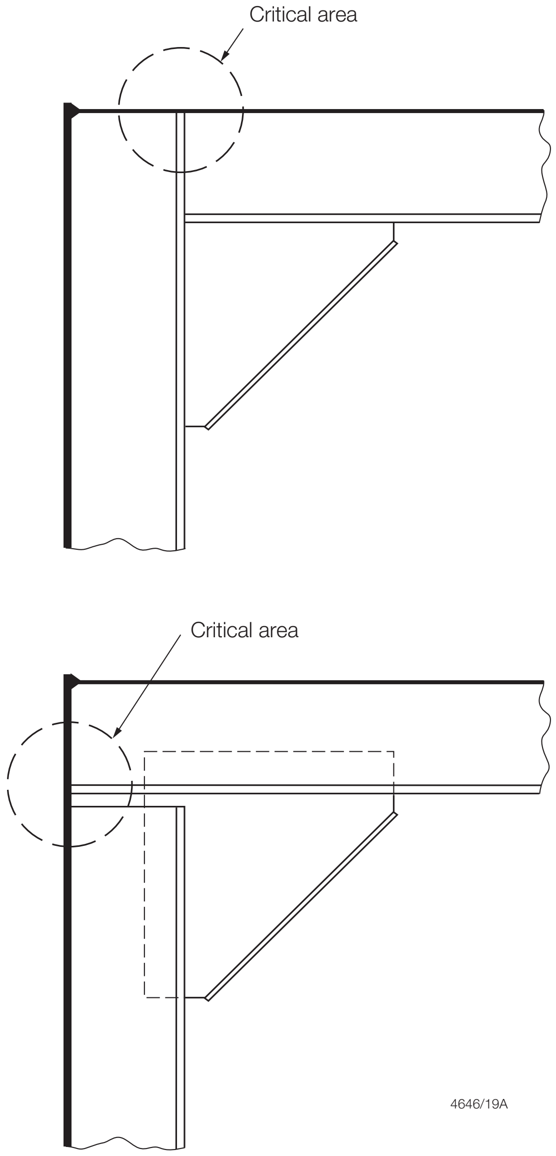
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	16

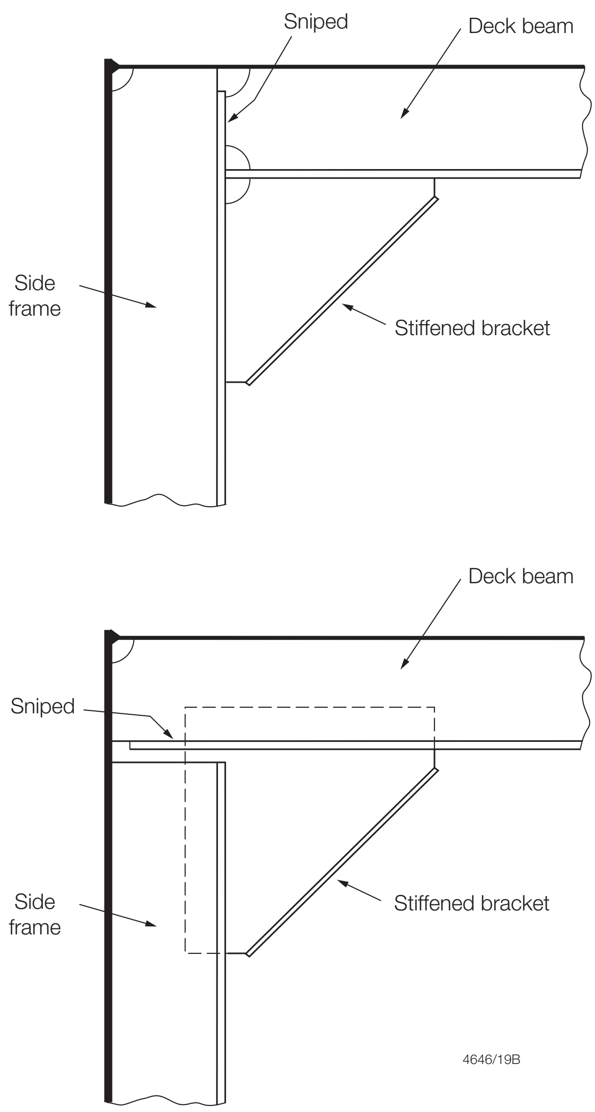
AREA: Hull internal structure

ITEM: Frame to beam connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





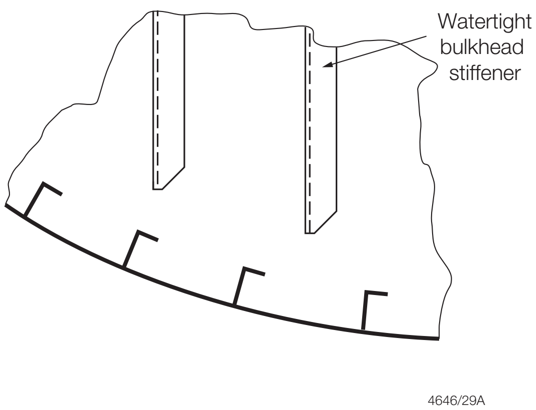
NOTES

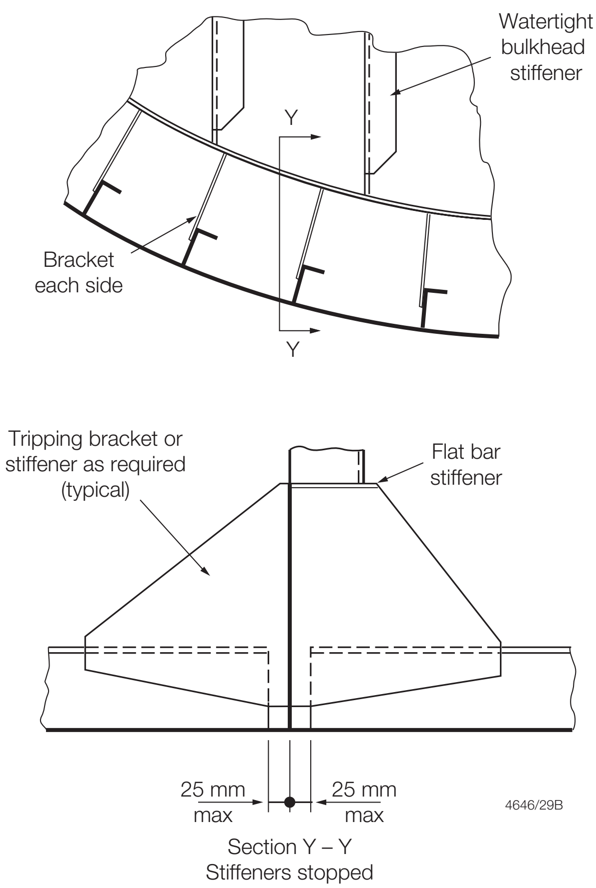
Failure Mechanism	Fractures in the shell and deck plating due to stress concentration arising from hard spots.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of deck beam to be accurately aligned with webs of frames. All welding in way of end connections and brackets is to be double continuous type. All welds to be returned around scallops.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 17

AREA:	Watertight/oiltight bulkheads with boundary bar
ITEM:	Shell longitudinals (lapped brackets)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT



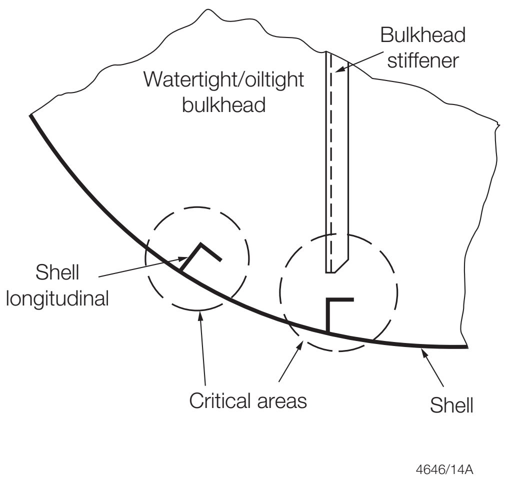
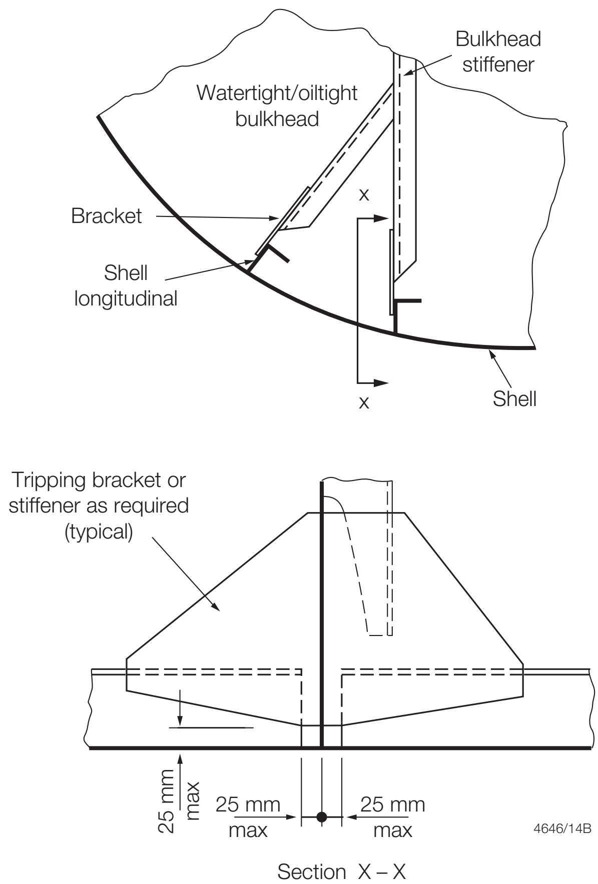


NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead platings. All welding in way of brackets and stiffener end connections is to be double continuous type.

GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 18

AREA:	Watertight/oiltight bulkheads
ITEM:	Shell longitudinals (lapped brackets)

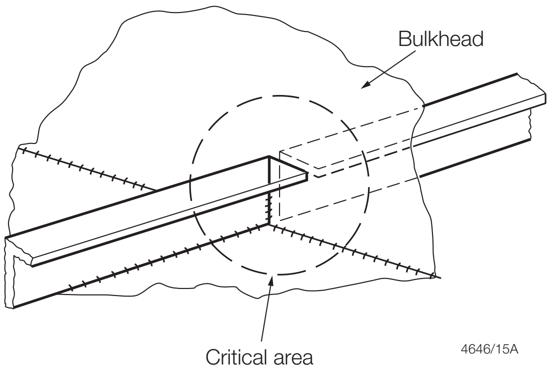
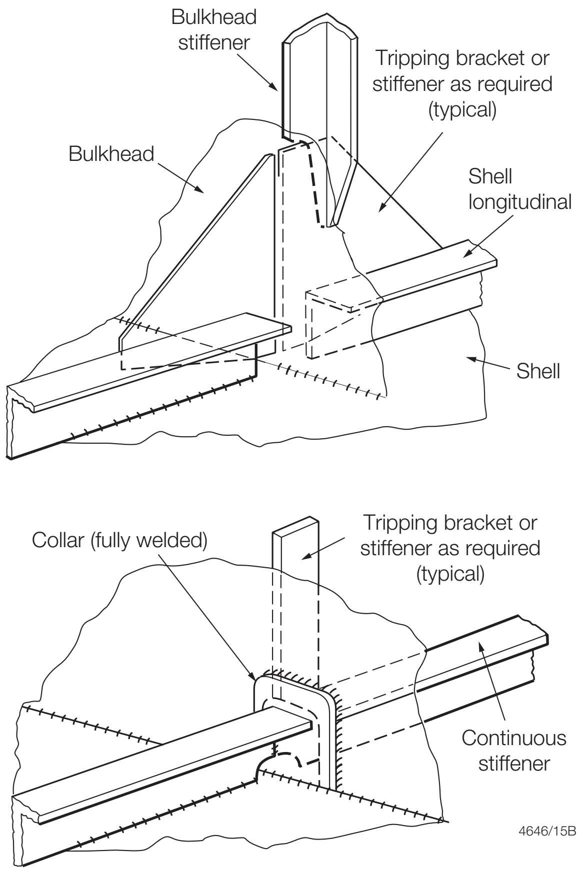
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of brackets are to be accurately aligned through the bulkhead platings. All welding in way of brackets and end connections of stiffeners is to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	19

AREA:	Watertight/oiltight bulkheads	Lloyd's Register
ITEM:	Shell longitudinals collared, brackets lapped	

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

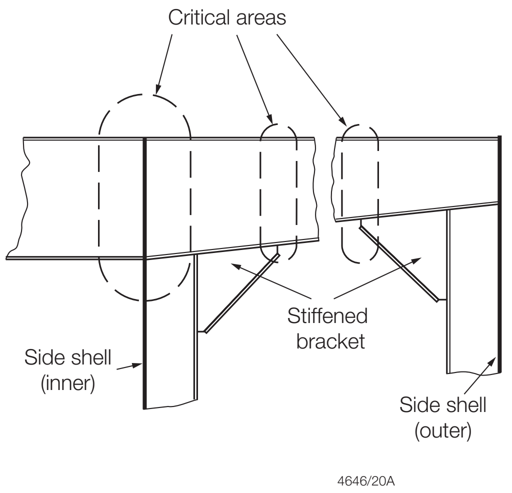
Failure Mechanism	Fractures in bulkhead plating arising from stress concentrations in way of longitudinal stiffener end connections.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding in way of collar and stiffener end connections is to be double continuous type. Welds are to be returned around scallops.

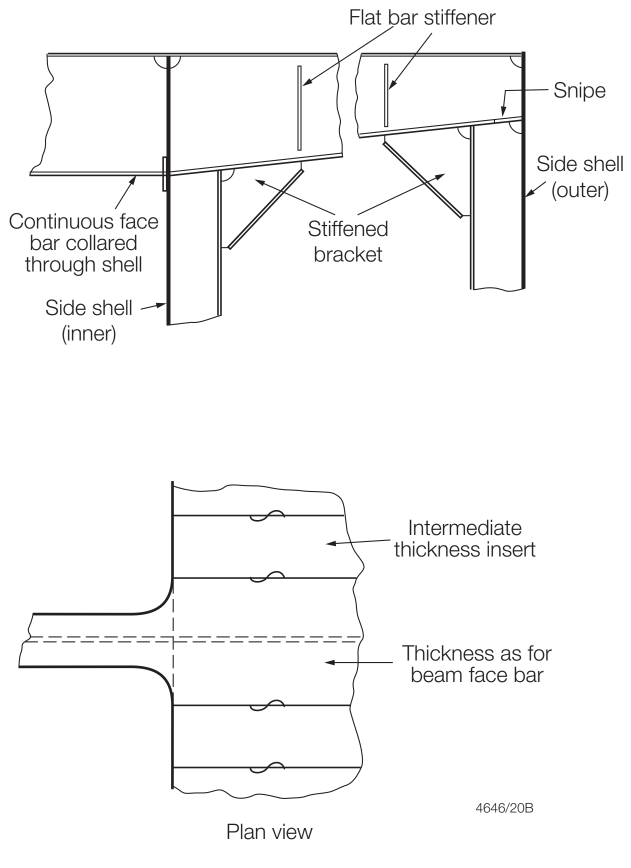
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	20

Detail Design Improvement for Steel/Aluminium Construction

AREA:	Cross-deck structure, multi-hulls
ITEM:	Connection between cross-deck beams and side hulls

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

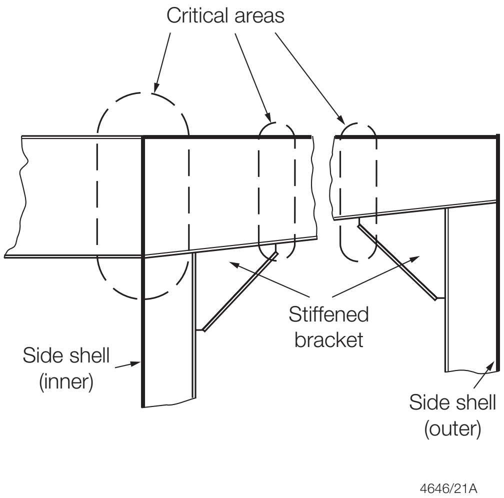
Failure Mechanism	Buckling of webs of cross-deck beams, and fracturing of deck plating in way of end connection due to hard spot.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with webs of cross-deck beams. All welds in way of end connection of frames are to be double continuous type. Webs of transverse beams are to be accurately aligned.

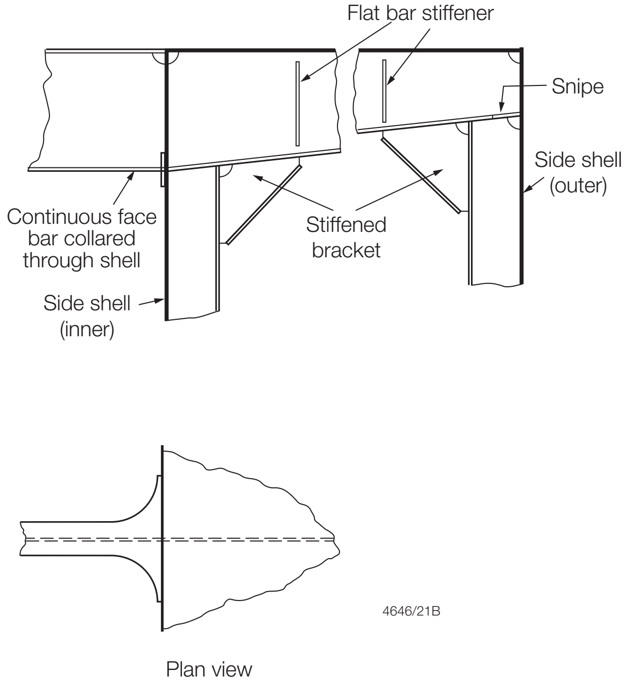
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	STEEL/ALUMINIUM CONSTRUCTION	21

Detail Design Improvement for Steel/Aluminium Construction

AREA:	Cross-deck structure, multi-hulls
ITEM:	Connection between cross-deck beams and side hulls

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of webs of cross-deck beams, and fracturing of deck plating in way of end connection due to hard spot.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with webs of cross-deck beams. All welds in way of end connections to be double continuous type. Webs of transverse beams are to be accurately aligned.

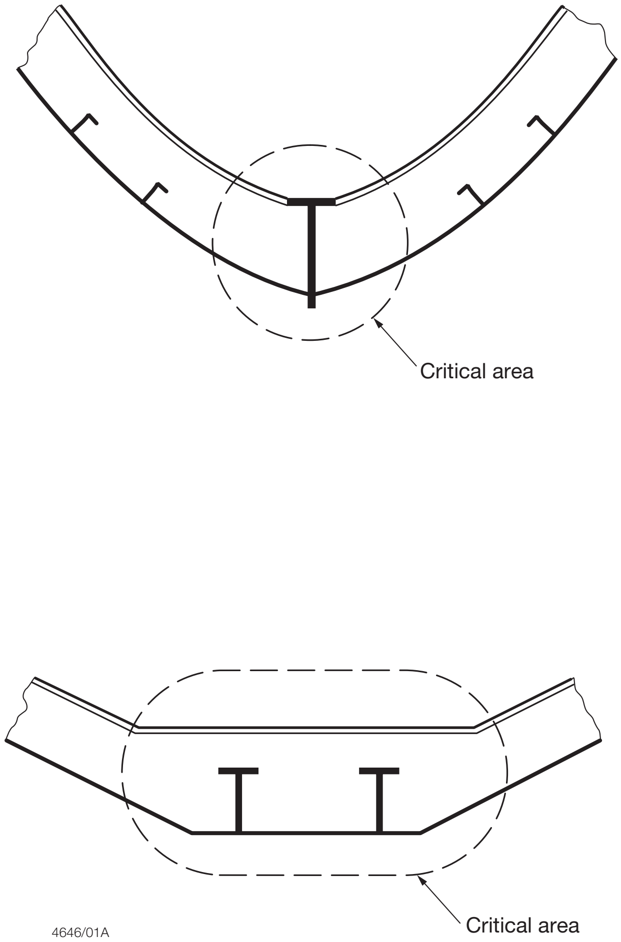
GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 22

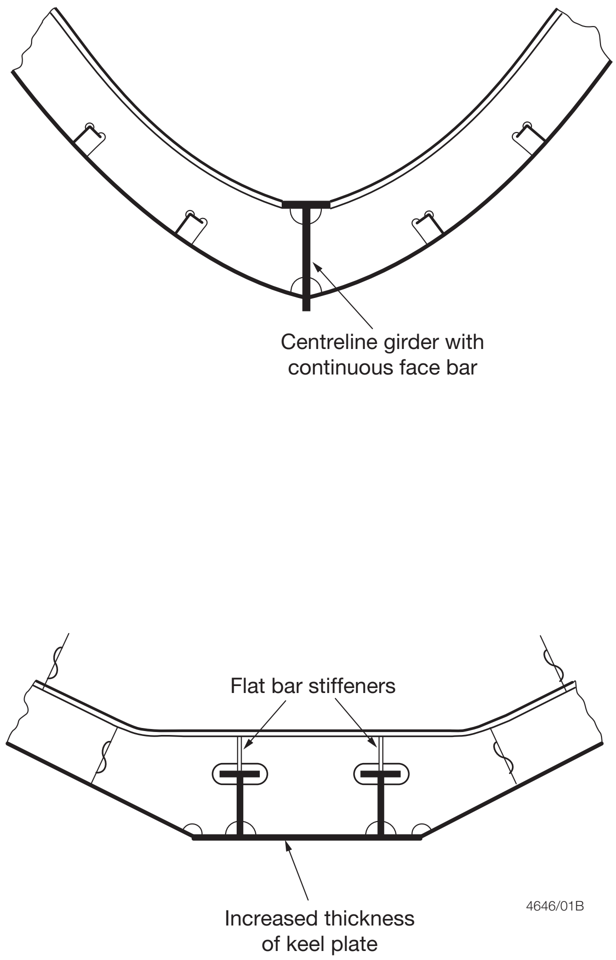
Detail Design Improvement for Steel/Aluminium Construction

AREA:	Hull centreline structure
ITEM:	Bar and plate keels

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fracturing of centre girder(s), buckling of keel plate and floors.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Butts in webs are to be staggered from butts in face flats.

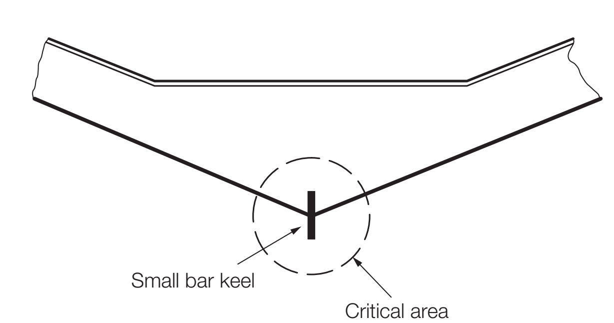
GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 23

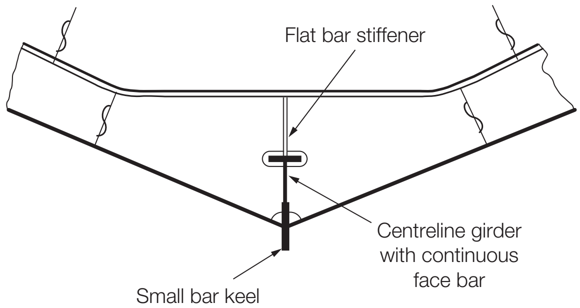
AREA: Hull centreline structure

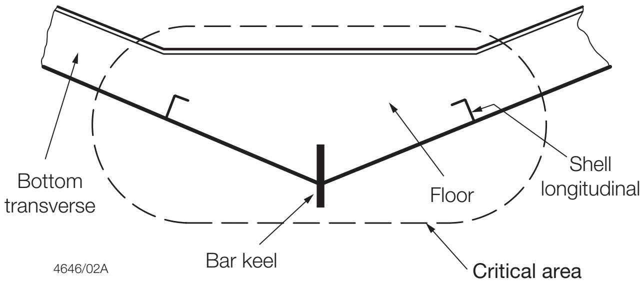
ITEM: Bar keels

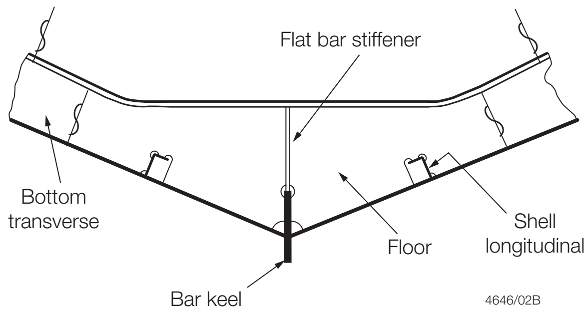
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

Failure Mechanism	Buckling of bar keel, shell plate and floors.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Butts in webs are to be staggered from butts in face flats.

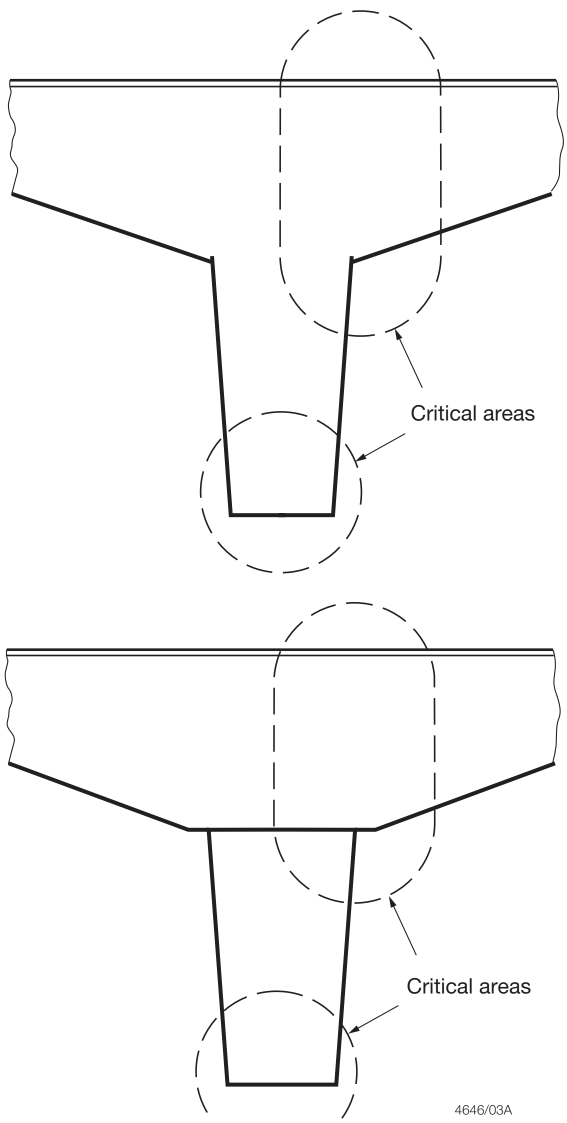
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	24

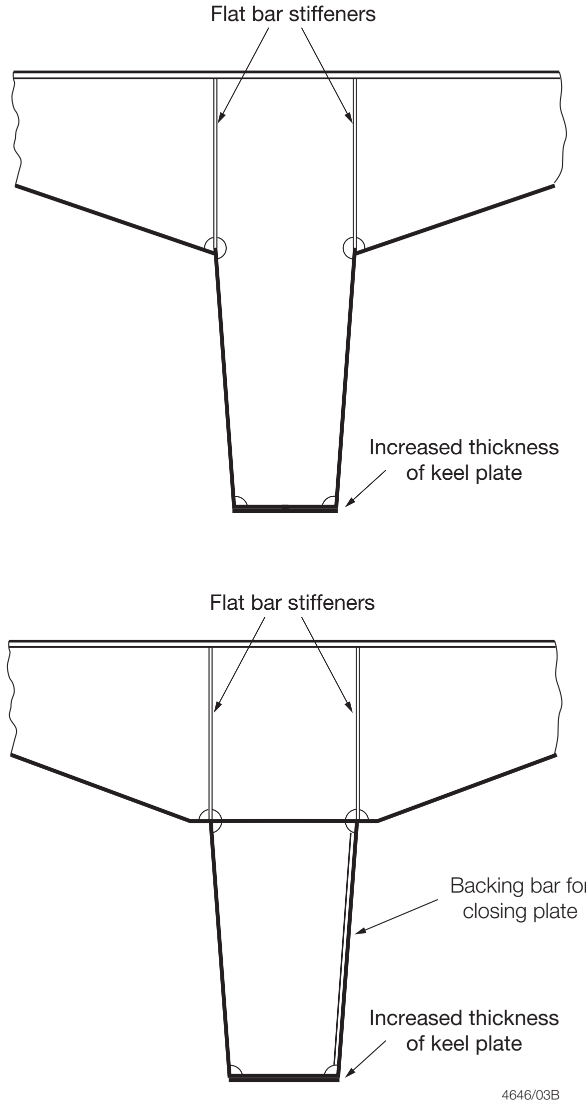
Detail Design Improvement for Steel/Aluminium Construction

AREA: Hull centreline structure

ITEM: Fabricated plate keel/skeg

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

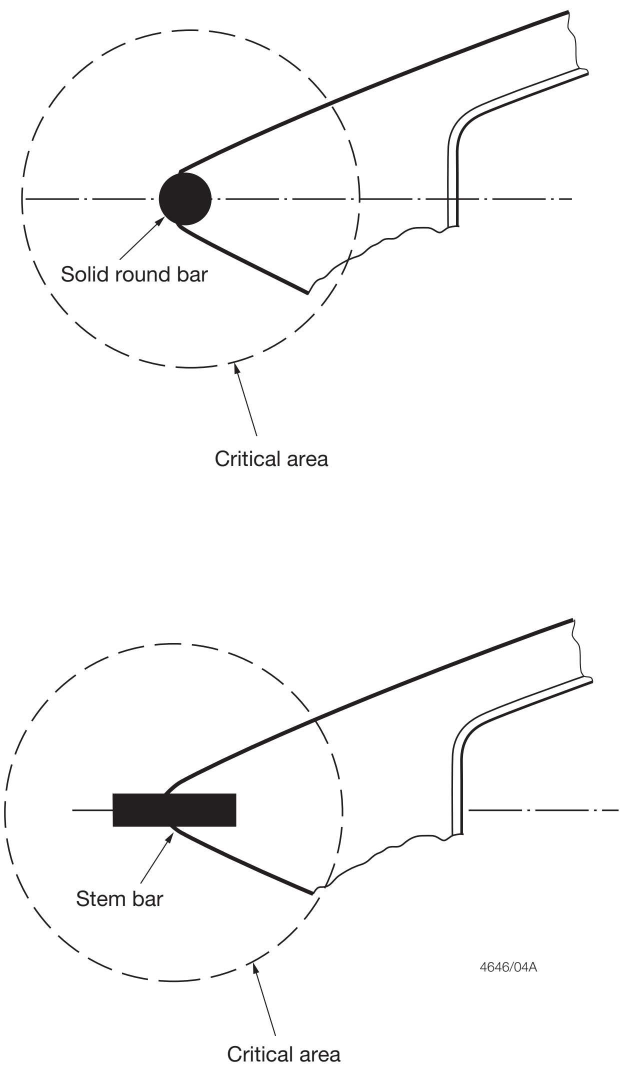
Failure Mechanism	Buckling of keel plate, shell and floor. Fractures from stress concentrations.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively.

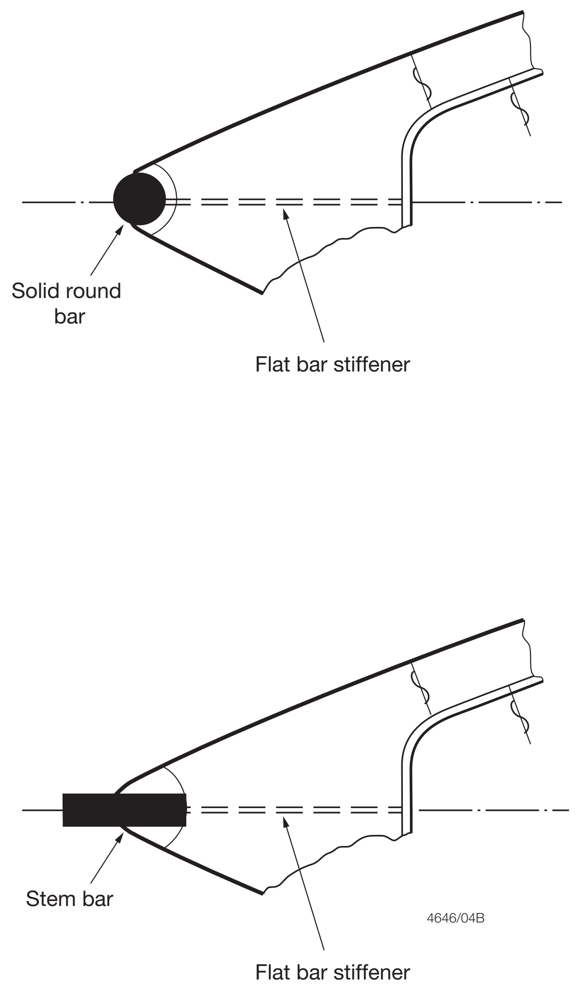
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	25

AREA:	Hull centreline structure
ITEM:	Round bar and flat bar stems

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Buckling of stem plating due to collision and impact with floating debris.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between stem bar and shell plating to be full penetration type. Butts in webs are to be staggered from butts in face flats.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	26

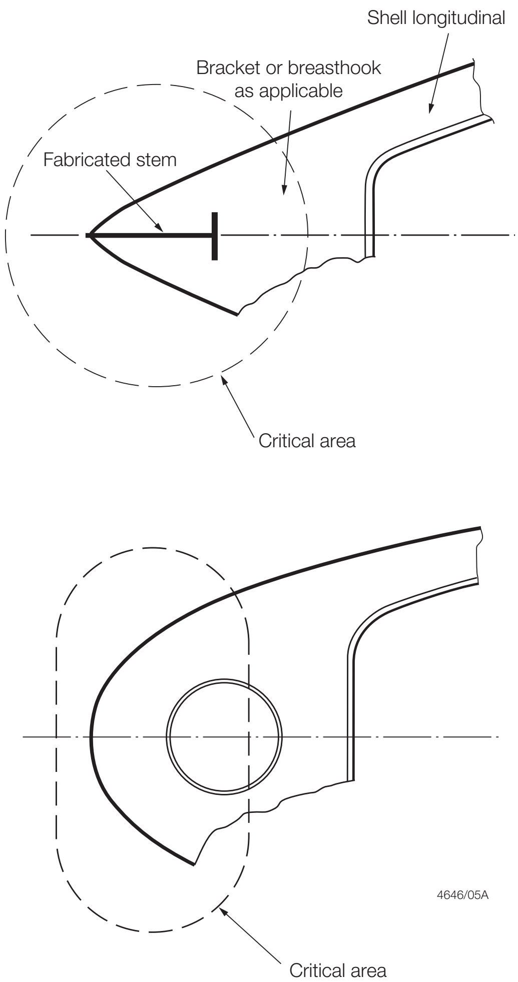
Detail Design Improvement for Steel/Aluminium Construction

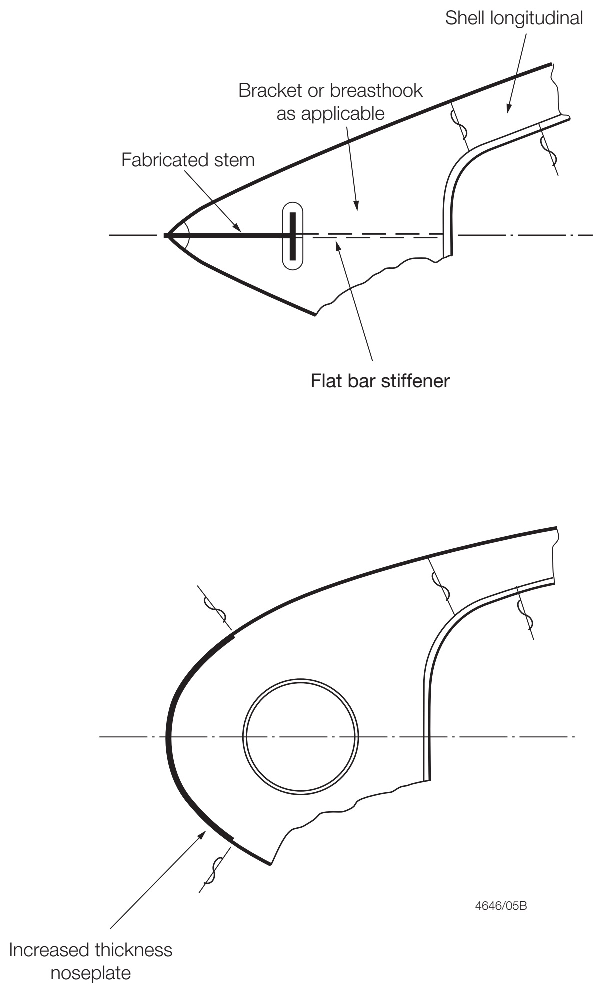
AREA: Hull centreline structure

ITEM: Fabricated and plate stems

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

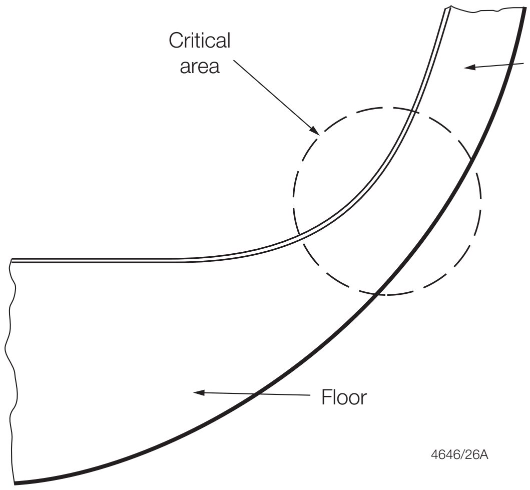
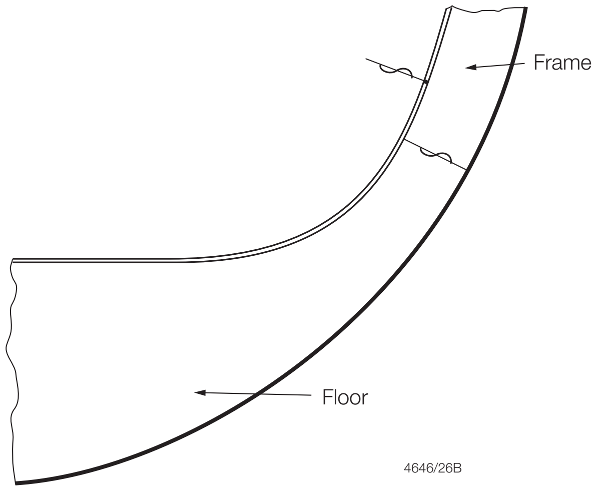
Failure Mechanism	Buckling of stem plating due to collision and impact with floating debris.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. All welding between stem and shell plating to be full penetration type. Butts in webs are to be staggered from the butts in face flats.

GROUP 3	GUIDANCE NOTES FOR DESIGN DETAILS STEEL/ALUMINIUM CONSTRUCTION	FIGURE 27

Detail Design Improvement for Steel/Aluminium Construction

AREA: Internal hull structure

ITEM: Floor to frame connection (radiused)

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
	

NOTES

Failure Mechanism	Fatigue fractures in way of welds.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs and face flats are to be accurately aligned with butts between face flats staggered from the butts in the frame webs.

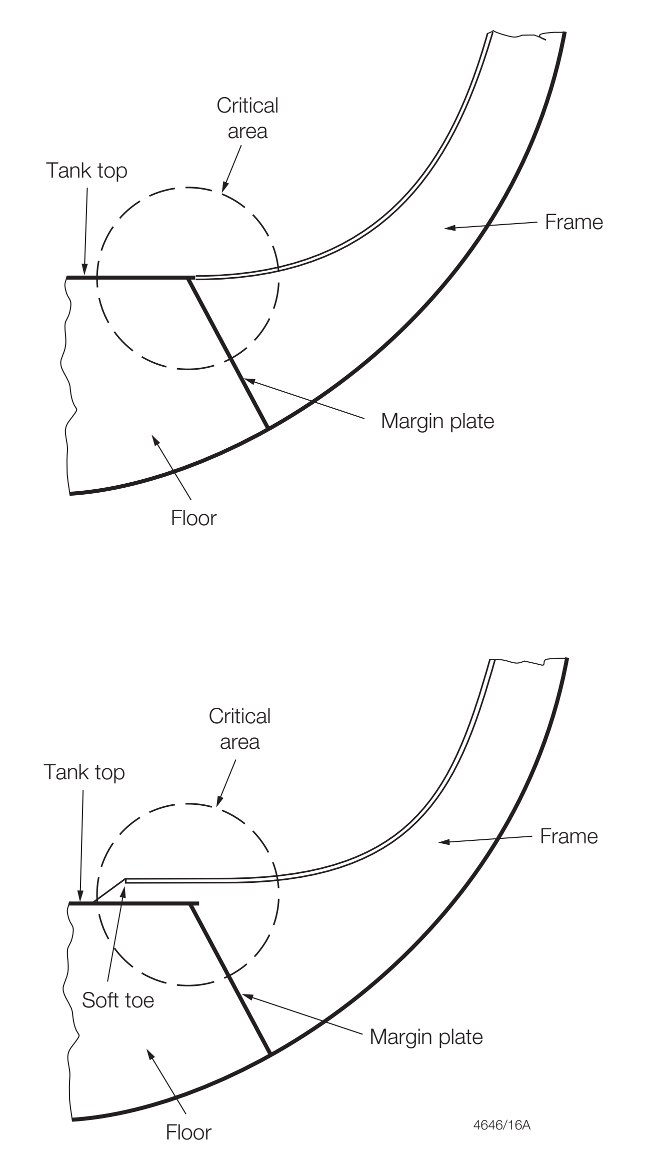
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	28

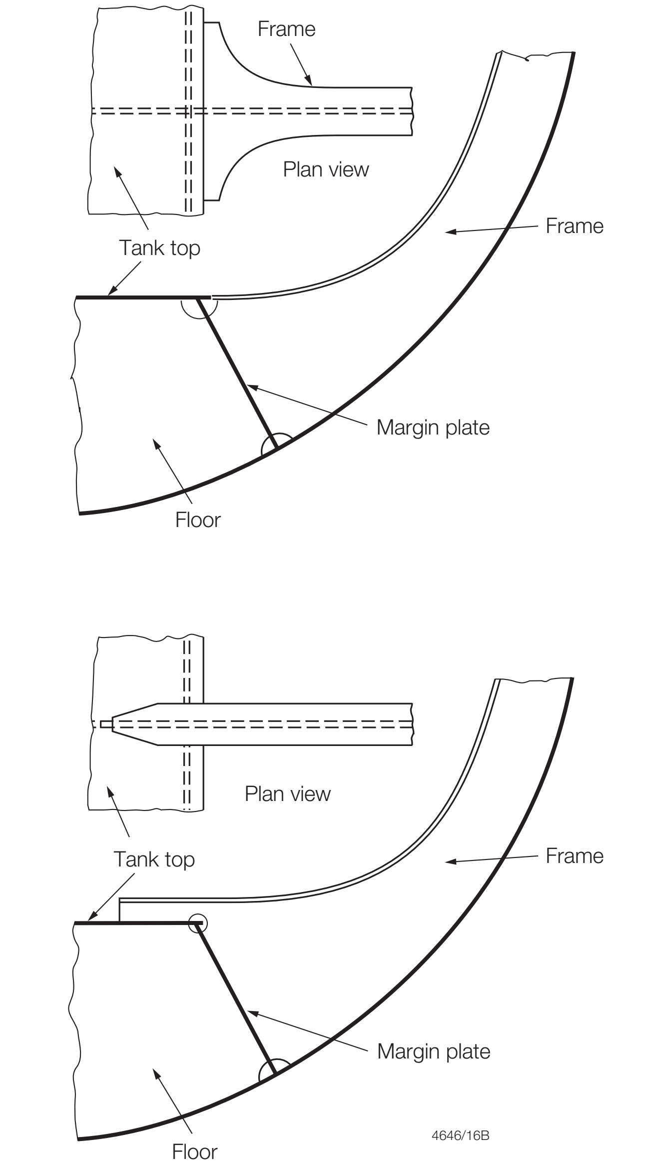
Detail Design Improvement for Steel/Aluminium Construction

AREA:	Hull internal structure
ITEM:	Web frame to tank boundary connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Fractures arising from stress concentrations.
Building Tolerance	To be in accordance with Pt 3, Ch 1 of the Rules for Special Service Craft.
Welding Requirements	To be in accordance with Pt 6, Ch 2 and Pt 7, Ch 2 of the Rules for Special Service Craft, for steel and aluminium alloy craft respectively. Webs of frames to be accurately aligned with floor plating. All welds in way of end connection of frames are to be double continuous type.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	STEEL/ALUMINIUM CONSTRUCTION	29

Detail Design Improvement for Composite Construction

Section

Section 1
Identification of critical areas

1.1 General

1.1.1 LR has applied direct calculation procedures in the structural appraisal and approval of new buildings and in various investigations on special service craft of composite construction. Through these procedures and the wealth of information collected on the LR fleet database, a number of locations have been identified where good design, workmanship and alignment during construction are particularly important. These are usually locations where high stress variations can be experienced during the lifetime of the craft. These are referred to to as critical locations and are highlighted in this Chapter.

1.1.2 This Chapter identifies the critical areas within various structural elements of the hull structure and transverse bulkheads.

1.1.3 In Section 2 the structural detail design improvements that can be applied to increase the fatigue life of the structural components are provided. These detail improvements are intended to give the designer guidance for meeting the design criteria for structural detail components.

1.1.4 The application of 2 and 3-dimensional finite element analyses techniques to the hull structure enables the global and local capabilities of the hull structure to withstand static and dynamic loadings to be assessed. Such analyses will enable those high stress locations and joints within the craft to be readily identified. Such locations will then, by their very nature, be at risk to fatigue damage unless appropriate measures are taken at the design stage and subsequently during construction.

1.1.5 Extensive 'in-service' experience of the performance of existing craft structures, already provide an awareness of those critical locations which merit particular attention either due to stress or alignment difficulties.

1.2 Critical areas

1.2.1 Stress concentrations occur in both the primary and secondary structures of all craft and are identified during the design process by such means as finite element calculations. The designer will modify the detail to alleviate the stress concentration either by redesign or increase in scantlings. However, even after modification that area will still, in general, be exposed throughout the life of the craft to stresses higher than in surrounding areas.

1.2.2 At the design appraisal stage, a plan of the structure should, where appropriate, be prepared by the Builder or designer indicating these regions, and consideration can then be given, by the production team, into the appropriate methods of construction and the tolerances to be applied in order to remain within the assigned design parameters.

1.3 Misalignment during construction

1.3.1 The very nature of composite construction involves the manufacture of the material at the same time as the product and therefore, the alignment of the moulds and formers is one of the major considerations. The bonded interface between structural components in sub-assembly areas, prefabrication stages must also be carefully controlled to ensure accurate alignment and to achieve a satisfactory bond.

1.3.2 The most critical type of joint is the bonded 'tee joint' where it is subjected to high magnitudes of tensile and shear stresses. Particular attention must also be given to the transition between different types of stiffener members i.e., top-hat to plate laminates.

1.3.3 It can readily be seen that the combination of stress concentration and misalignment is to be avoided if the fatigue strength is to be satisfactory during the service life of the craft.

1.4 Fatigue considerations

1.4.1 The bottom shell area of high speed craft is subjected to the highest cyclic loading throughout the life of such craft.

1.4.2 The fatigue cracks in bottom shell laminates in way of internal hard spots, and in way of longitudinal end-connections, has been well documented. Constructional details in way of these areas, designed to increase fatigue life, are now incorporated by many Builders as standard. It is, therefore, important that due consideration be given to these details at the design stage to reduce the risk of fatigue cracking during service.

1.4.3 Detailed recommendations are detailed herein for the critical areas, *see* Section 2.

Section 2
Structural details

2.1 Detail design improvement

2.1.1 For the purposes of these Guidance Notes, structural locations have been divided into five separate groups, with a series of examples of critical structural areas together with alternative associated detail design improvements.

2.1.2 A summary of the data presented is given in Table 5.2.1 whilst the full details are given in Figs. 1 to 30 as contained in this Section.

2.1.3 Generally, where alternative structural detail design improvements are provided, the details shown will provide improved fatigue strength.

2.1.4 Where ‘top-hat’ sections are shown, the same requirements apply to plate and other stiffening members sections.

Table 5.2.1

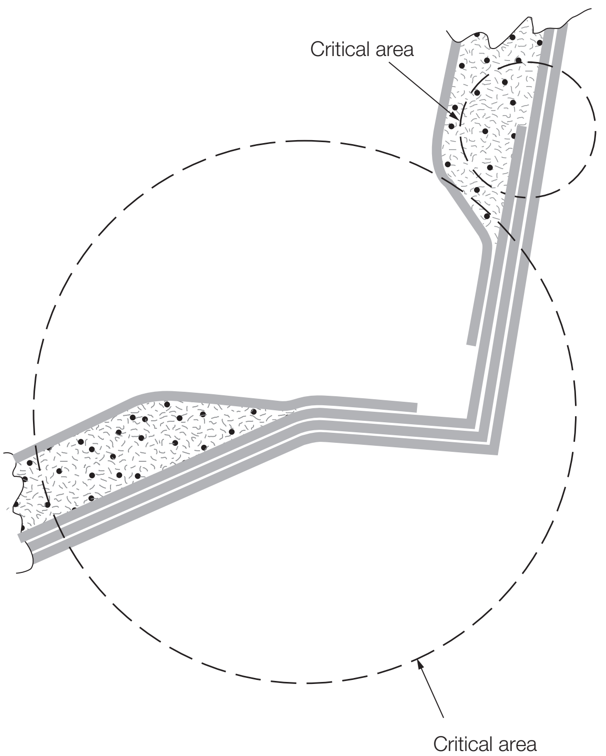
Group	Application	Area	Item	Fig. No
	High speed craft			
1	Sandwich	Chine in way of side shell and bottom shell connection	Chine reinforcement	1
		Stem	Stem reinforcement	2
		Hull bottom structure	Bulkhead to hull connection	3
		Hull bottom structure	Bulkhead to hull connection	4
2	Single skin	Hull structure	Spray rails	5
		Hull structure	Spray rails	6
		Chine in way of side shell and bottom shell connection	Chine reinforcement	7
		Hull internal structure	Bulkhead to hull connection	8
		Hull internal structure	Bulkhead to hull connection	9
	Low speed craft			
3	Sandwich	Hull internal structure	Bulkhead to hull connection	10
		Hull internal structure	Bulkhead to hull connection	11
4	Single skin	Hull bottom structure	Bulkhead to hull connection	12
		Hull bottom structure	Bulkhead to hull connection	13
5	General detail	Hull centreline structure	Keel/stem reinforcement and keel stiffening	14
		Hull centreline structure	Keel/stem reinforcement and keel stiffening	15
		Hull structure	Deck to hull connection	16
		Hull structure	Transom boundary	17
		Hull structure	Deck to hull connection	18
		Hull bottom structure	Limber holes	19
		Hull bottom structure	Machinery seating, tapping plates	20
		Hull internal structure	Deep girders and floors	21
		Hull internal structure	‘Top-hat’ stiffeners penetrating tank boundaries	22
		Hull internal structure	Lower deck/tank top to bottom shell connection	23
		Hull internal structure	Integral tanks access manholes	24
		Skeg (open type)	Skeg stiffening and reinforcement	25
		Skeg (closed type)	Skeg diaphragm plates and sealing laminate	26
		Deck structure	Well deck, lower/sole deck to hull connection	27
		Deck structure	Well deck, lower/sole deck to hull connection	28
		Deck	Bulkhead to deck connection	29
		Deck	Deckhouse to deck connection	30

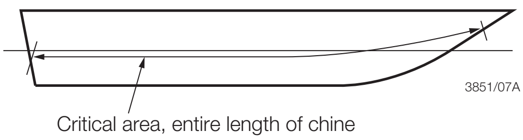
AREA:	Chine in way of side shell and bottom shell connection
ITEM:	Chine reinforcement

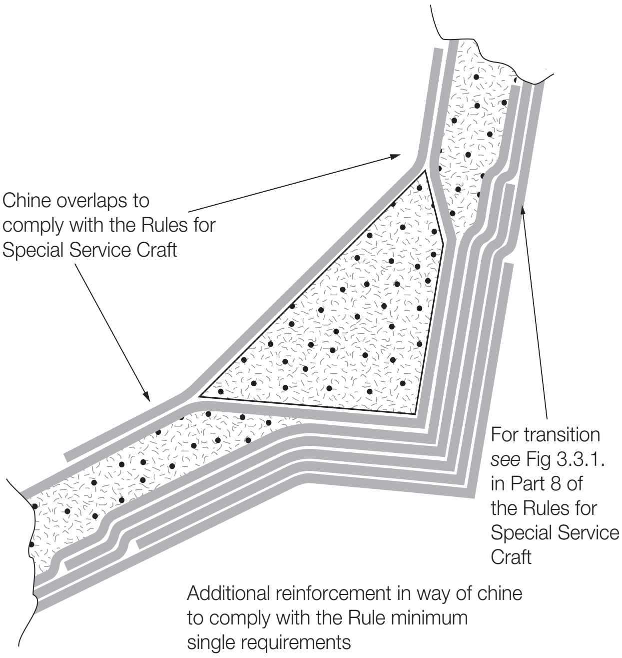
Lloyd's Register

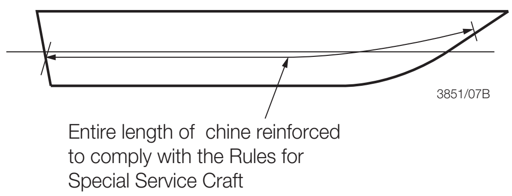
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction









NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging, hydrodynamic and other types of impact.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	1

Detail Design Improvement for Composite Construction

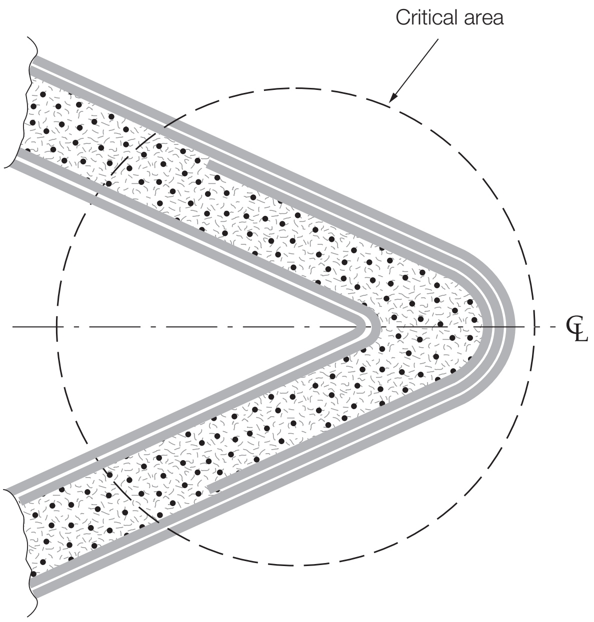
AREA: Stem

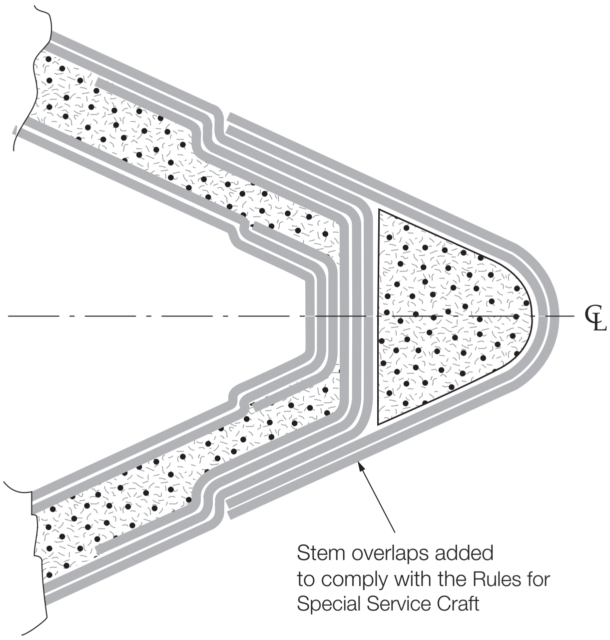
ITEM: Stem reinforcement

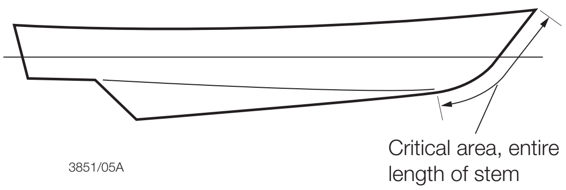
Lloyd's Register

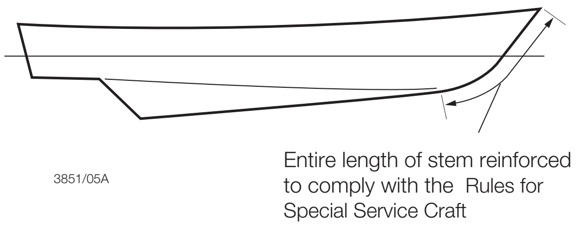
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction









NOTES

Failure Mechanism	Excess loads due to collision and impact with floating debris.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	2

Detail Design Improvement for Composite Construction

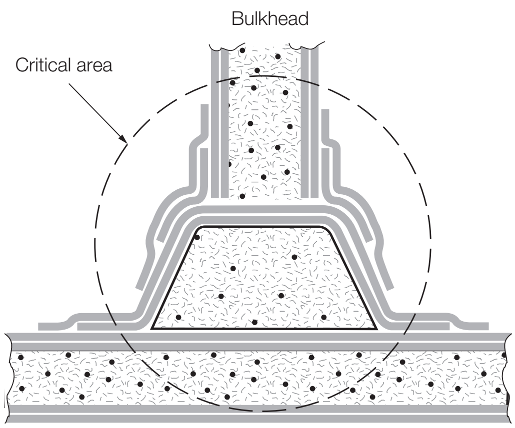
AREA: Hull bottom structure

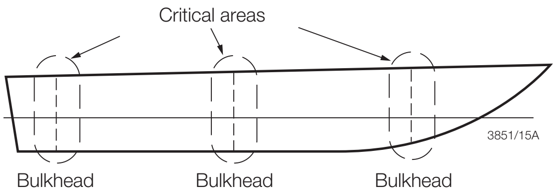
ITEM: Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

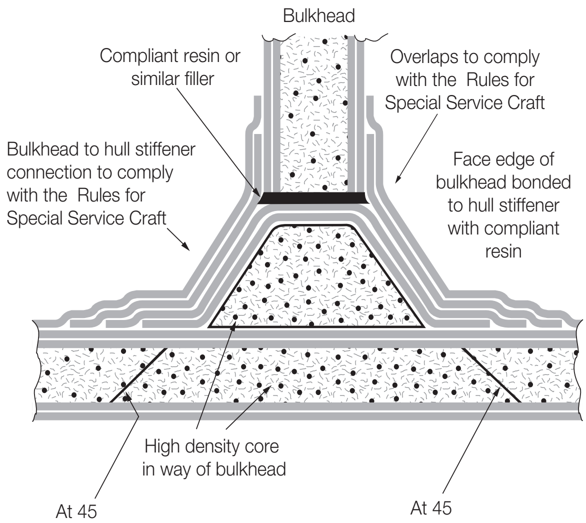
CRITICAL AREAS

Sandwich construction, high speed

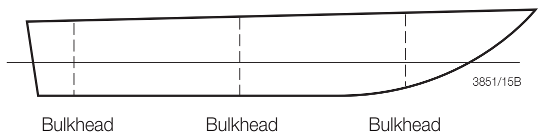




DETAIL DESIGN IMPROVEMENT



All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 1	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 3

Detail Design Improvement for Composite Construction

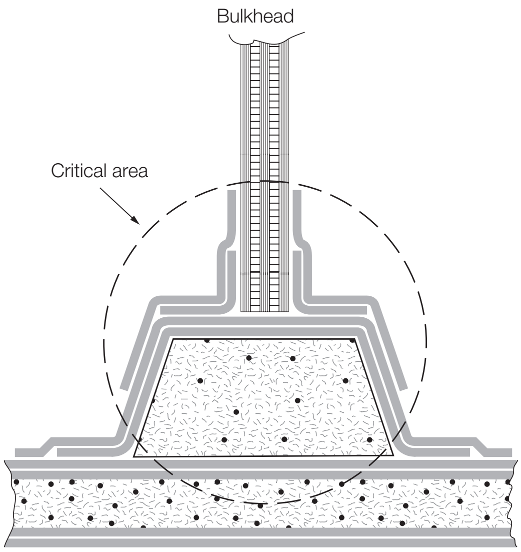
AREA: Hull bottom structure

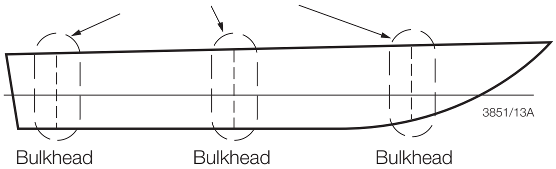
ITEM: Bulkhead to hull connection

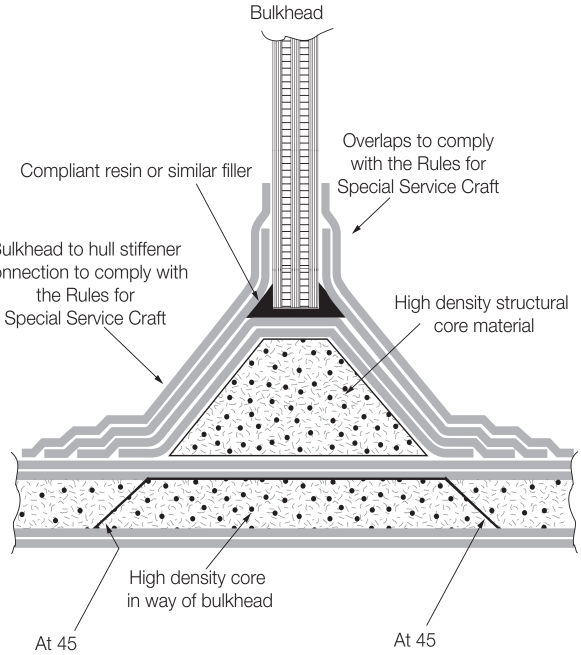
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

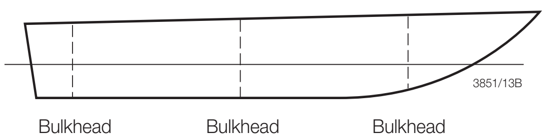
Sandwich construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
1	COMPOSITE CONSTRUCTION	4

Detail Design Improvement for Composite Construction

Chapter 5

Section 2

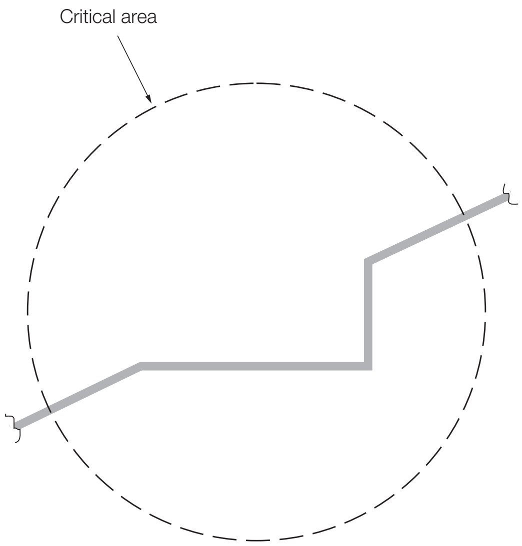
AREA: Hull structure

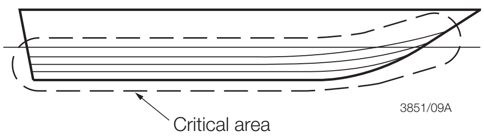
ITEM: Spray rails

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

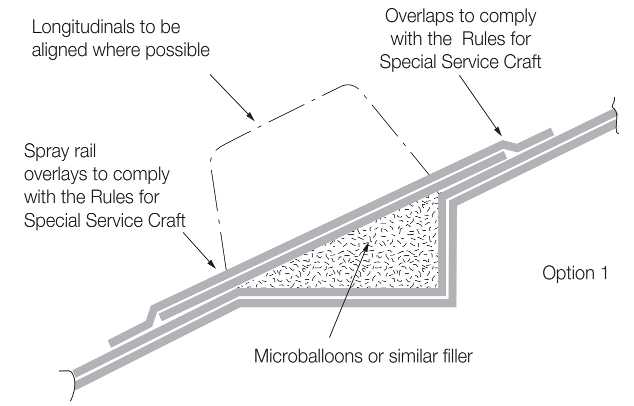
CRITICAL AREAS

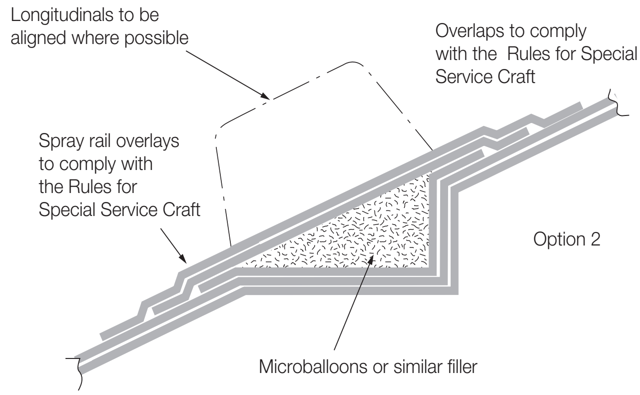
Single skin construction

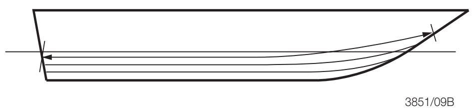




DETAIL DESIGN IMPROVEMENT







Entire length of spray rails overlaid to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to grounding and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	5

Detail Design Improvement for Composite Construction

Chapter 5

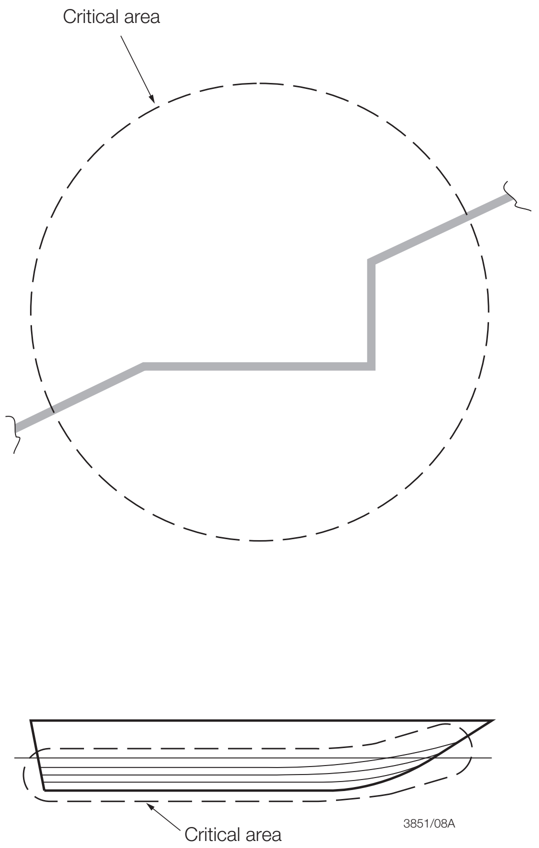
Section 2

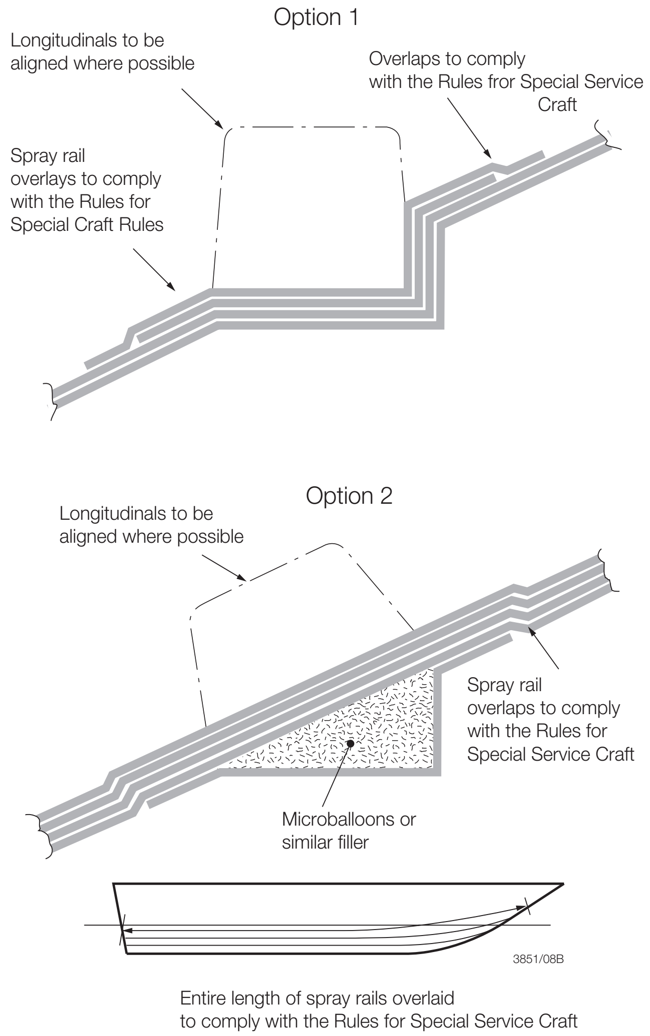
AREA:	Hull structure
ITEM:	Spray rails

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction





NOTES

Failure Mechanism	Excess loads due to grounding and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	6

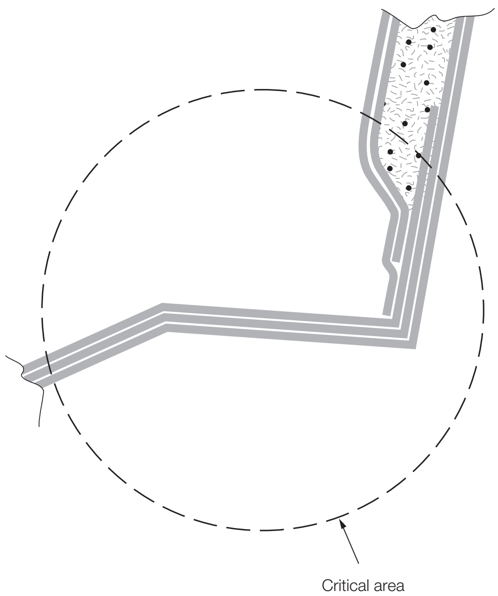
Detail Design Improvement for Composite Construction

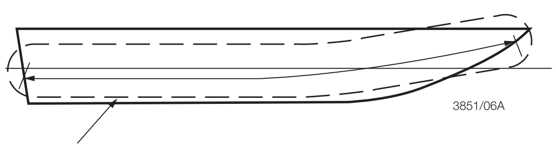
AREA:	Chine in way of side shell and bottom shell connection
ITEM:	Chine reinforcement

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Critical areas

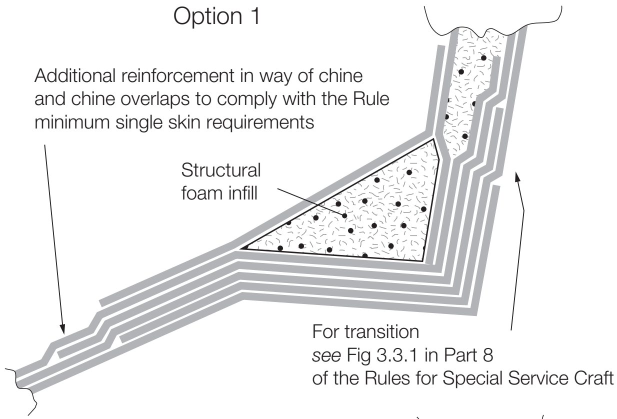
Sandwich side and single skin bottom



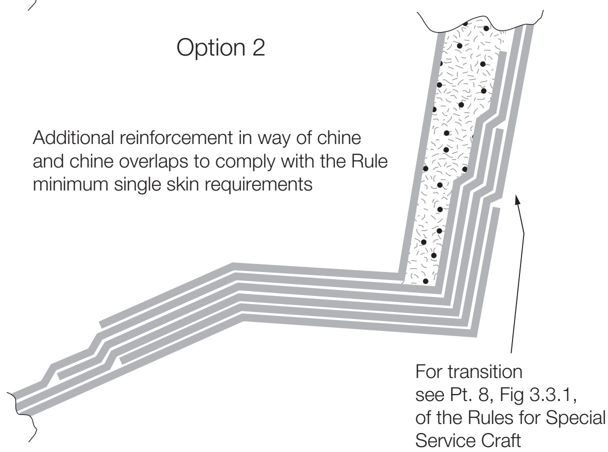


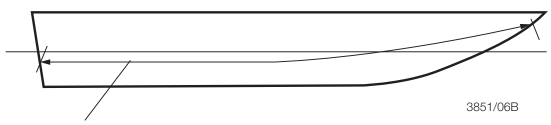
Detail design improvement

Option 1



Option 2





NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrodynamic impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

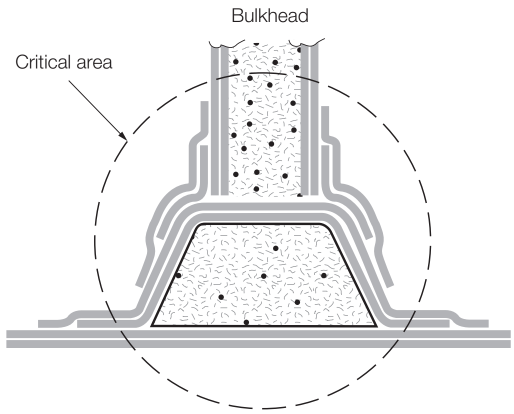
GROUP 2	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 7

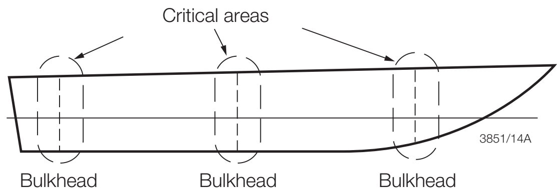
Detail Design Improvement for Composite Construction

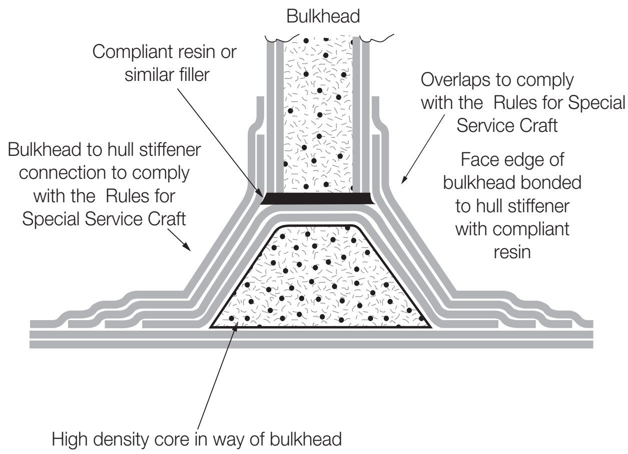
AREA:	Hull internal structure
ITEM:	Bulkhead to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

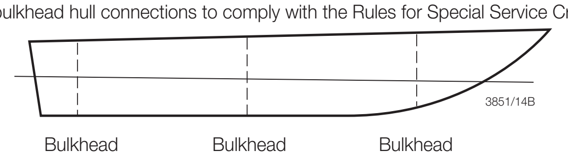
Single skin construction, high speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	8

Detail Design Improvement for Composite Construction

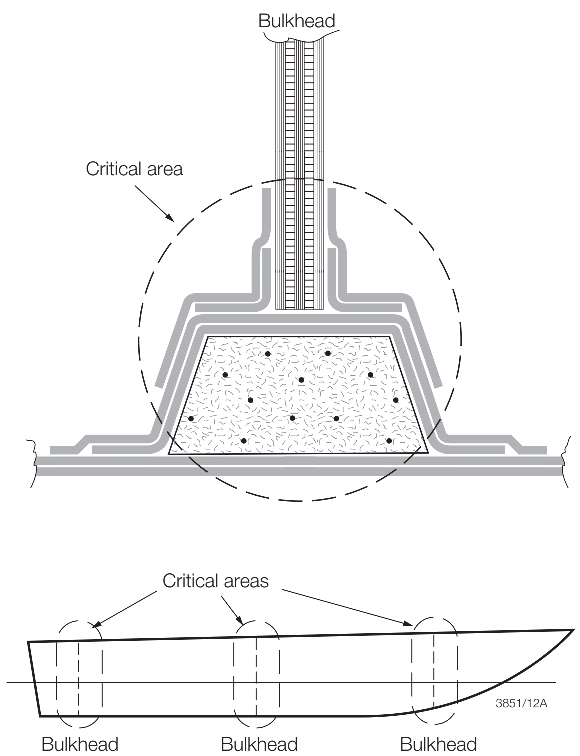
AREA: Hull internal structure

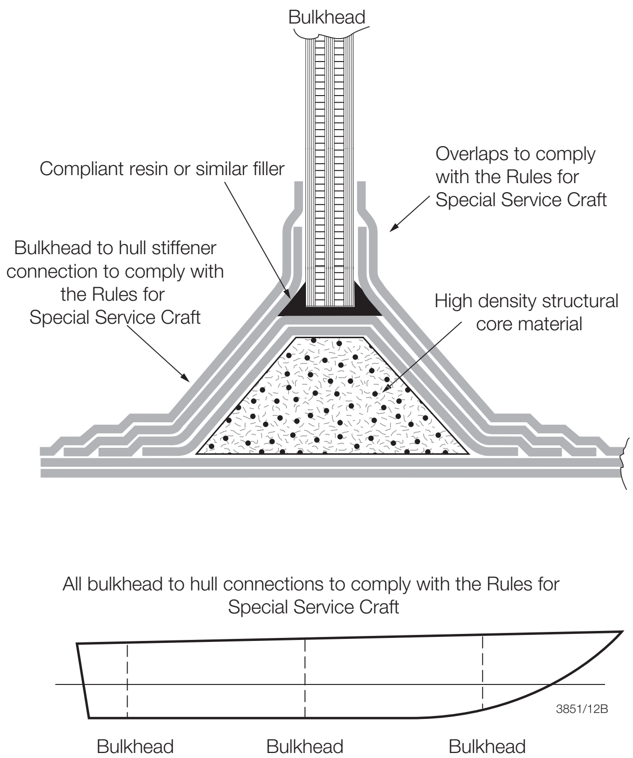
ITEM: Bulkhead to hull connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction, high speed





NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
2	COMPOSITE CONSTRUCTION	9

Detail Design Improvement for Composite Construction

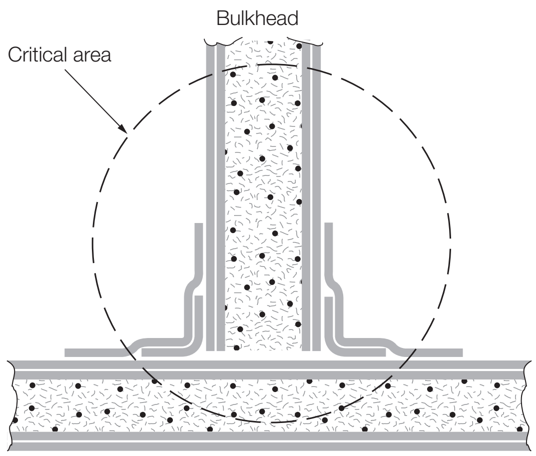
AREA: Hull internal structure

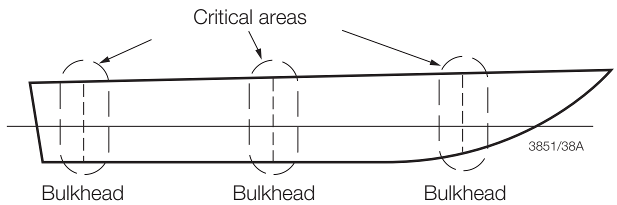
ITEM: Bulkhead to hull connection

Lloyd's Register

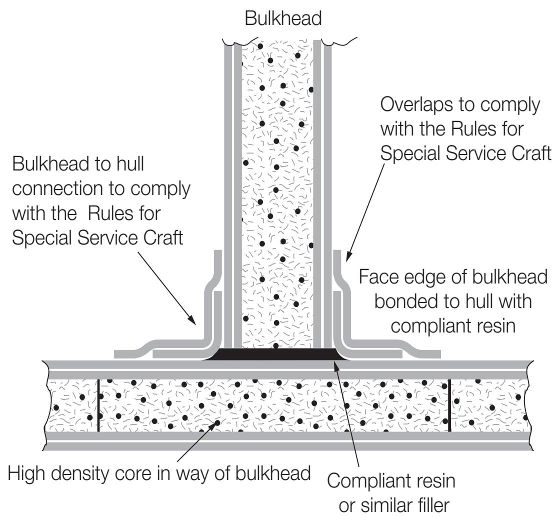
CRITICAL AREAS

Sandwich construction, low speed

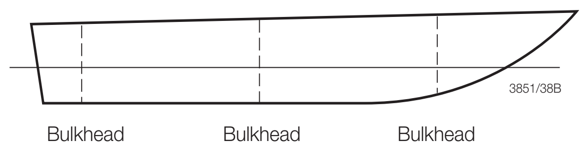




DETAIL DESIGN IMPROVEMENT



All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	COMPOSITE CONSTRUCTION	10

Detail Design Improvement for Composite Construction

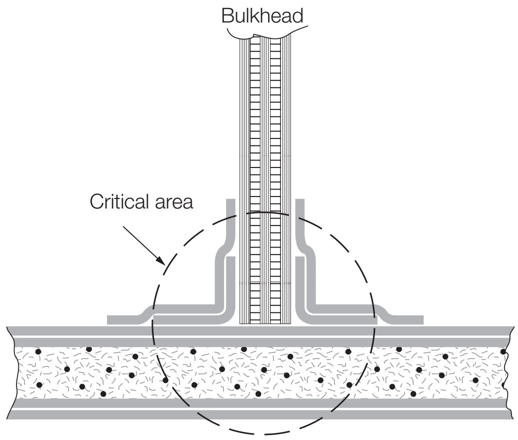
Chapter 5
Section 2

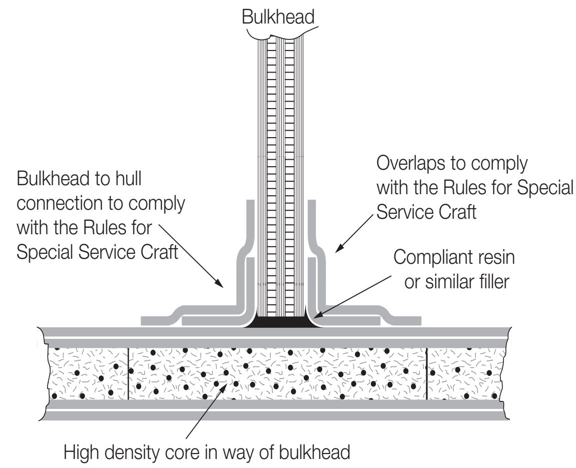
AREA:	Hull internal structure
ITEM:	Bulkhead to hull connection

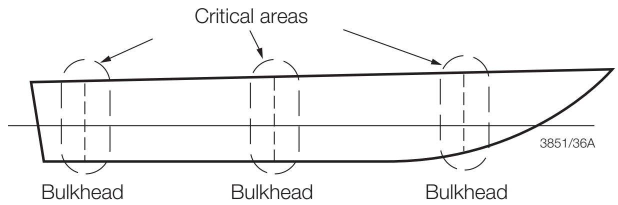
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

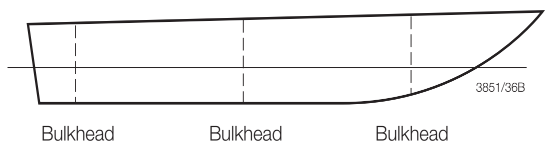
Sandwich construction, low speed







All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
3	COMPOSITE CONSTRUCTION	11

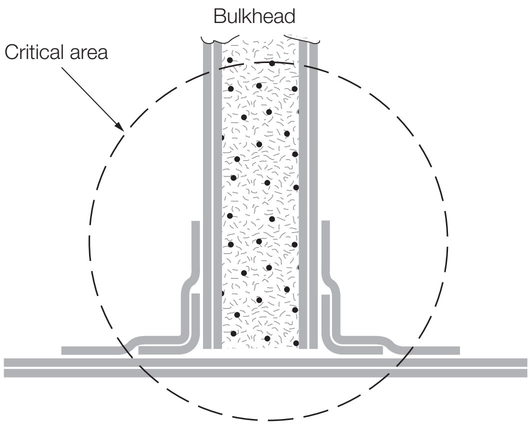
Detail Design Improvement for Composite Construction

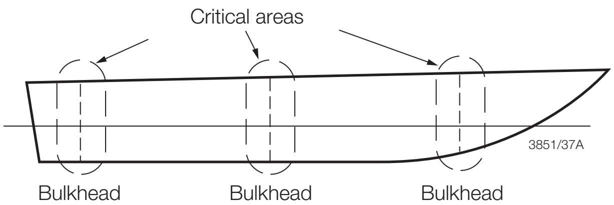
AREA: Hull bottom structure

ITEM: Bulkhead to hull connection

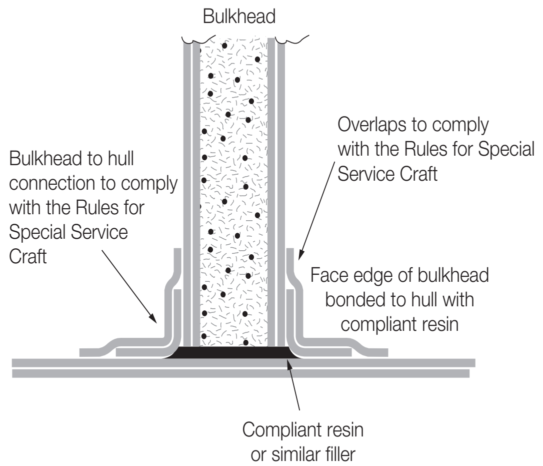
CRITICAL AREAS

Single skin construction, low speed

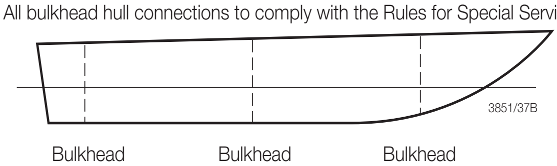




DETAIL DESIGN IMPROVEMENT



All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 4	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 12

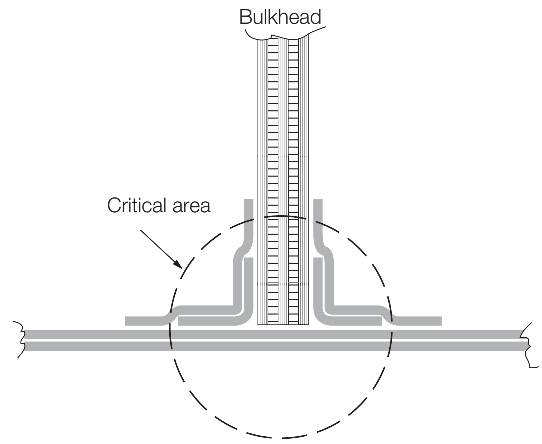
Detail Design Improvement for Composite Construction

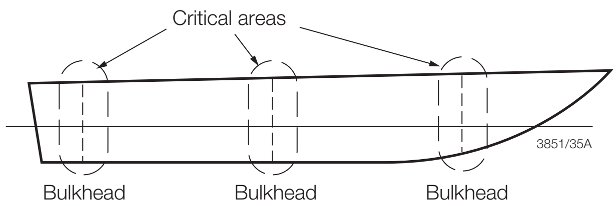
AREA: Hull bottom structure

ITEM: Bulkhead to hull connection

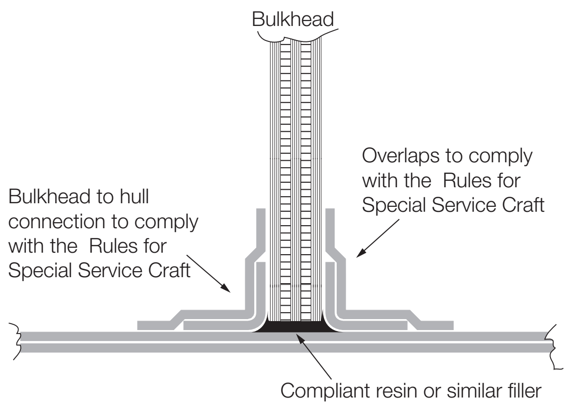
CRITICAL AREAS

Single skin construction, low speed

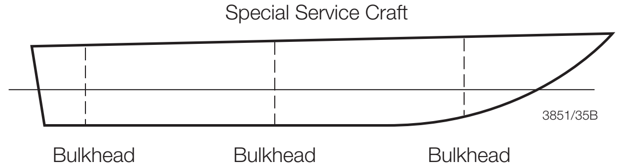




DETAIL DESIGN IMPROVEMENT



All bulkhead to hull connections to comply with the Rules for Special Service Craft



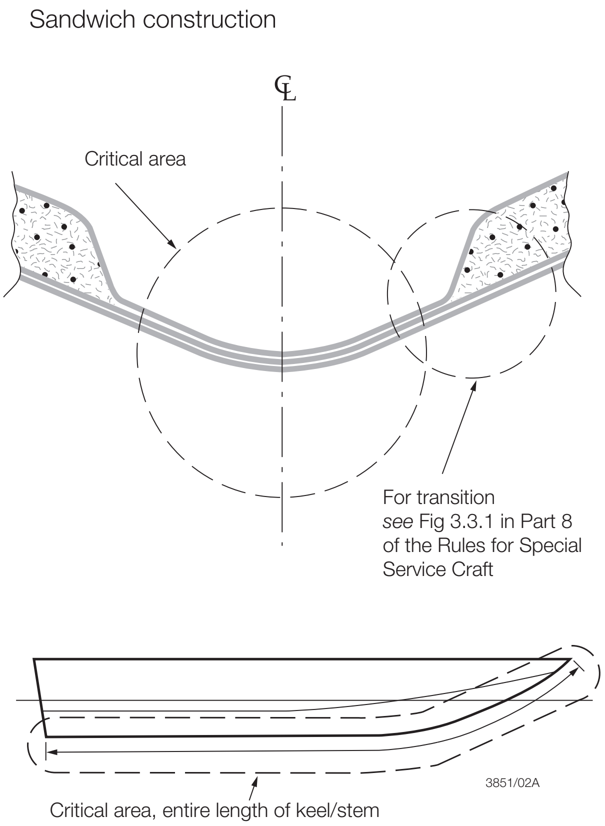
NOTES

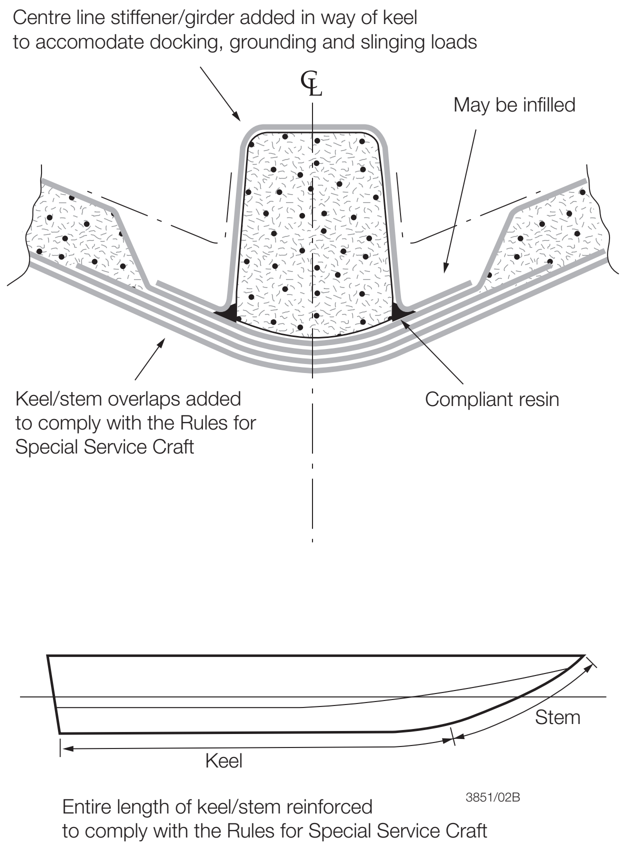
Failure Mechanism	Excess loads due to berthing, slinging, impact and racking.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
4	COMPOSITE CONSTRUCTION	13

AREA:	Hull centreline structure
ITEM:	Keel/stem reinforcement and keel stiffening

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Excess loads due to grounding, docking and slinging.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with the Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	14

Detail Design Improvement for Composite Construction

AREA: Hull centreline structure

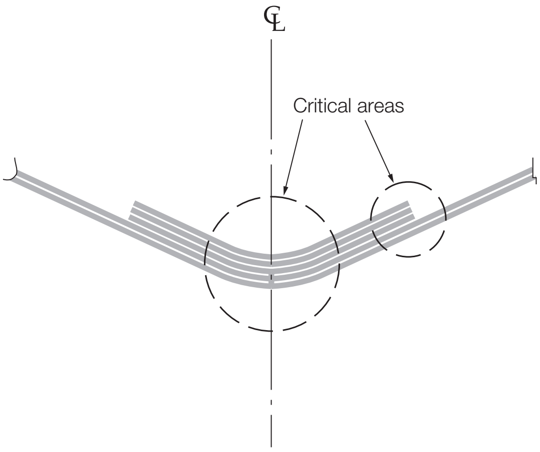
ITEM: Keel/stem reinforcement and keel stiffening

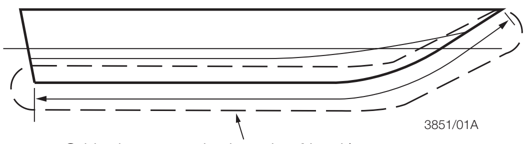
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

CRITICAL AREAS

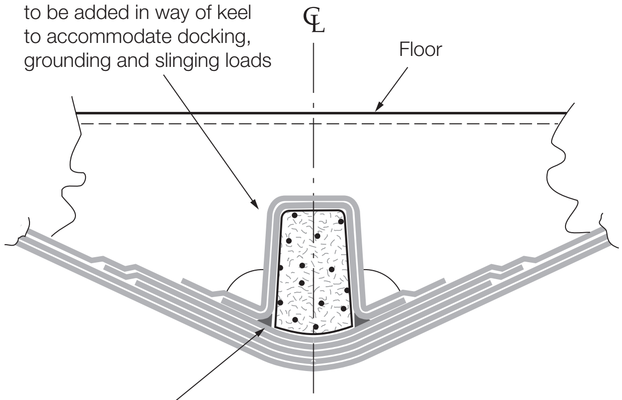
Single skin construction

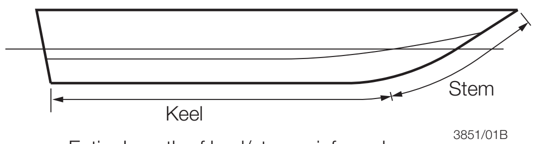




Critical area, entire length of keel/stem

DETAIL DESIGN IMPROVEMENT





Entire Length of keel/stem reinforced to comply with the Rules for Special Service Craft

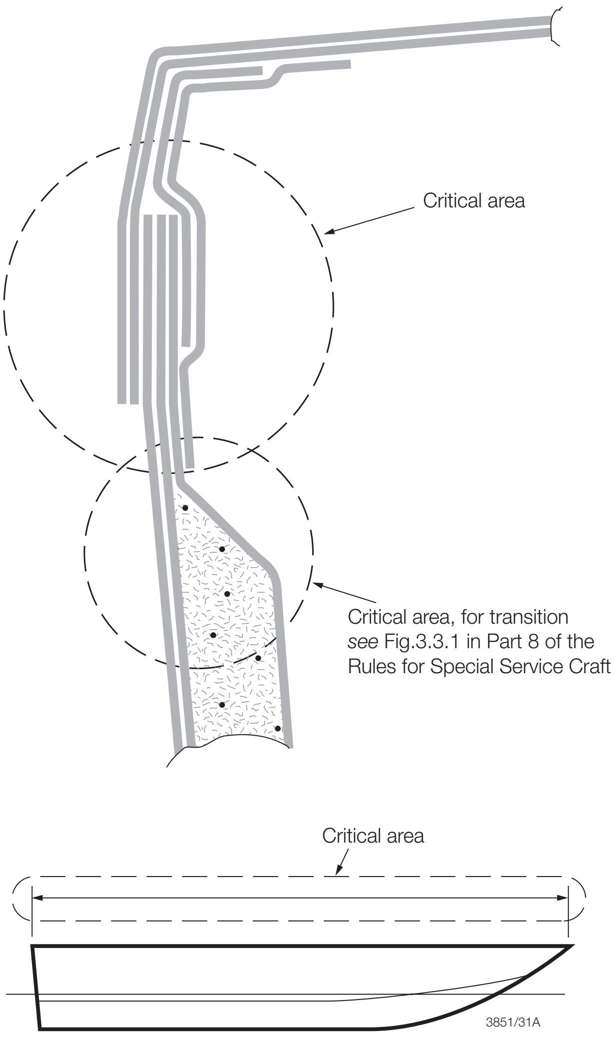
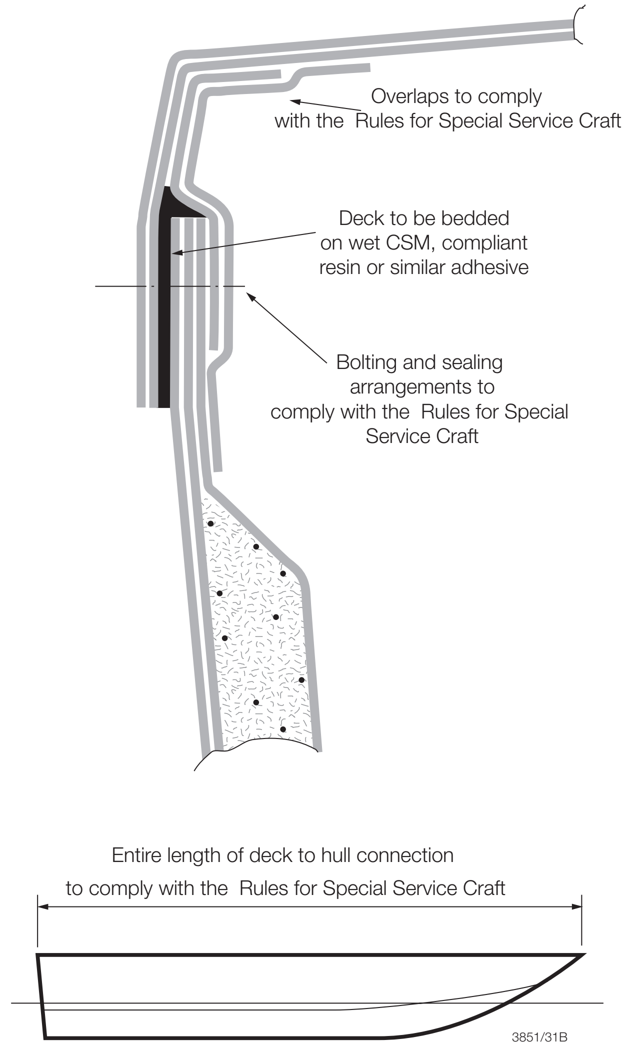
NOTES

Failure Mechanism	Excess loads due to grounding, docking and slinging.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	15

AREA: Hull structure

ITEM: Deck to hull connection

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT
Sandwich construction 	

NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

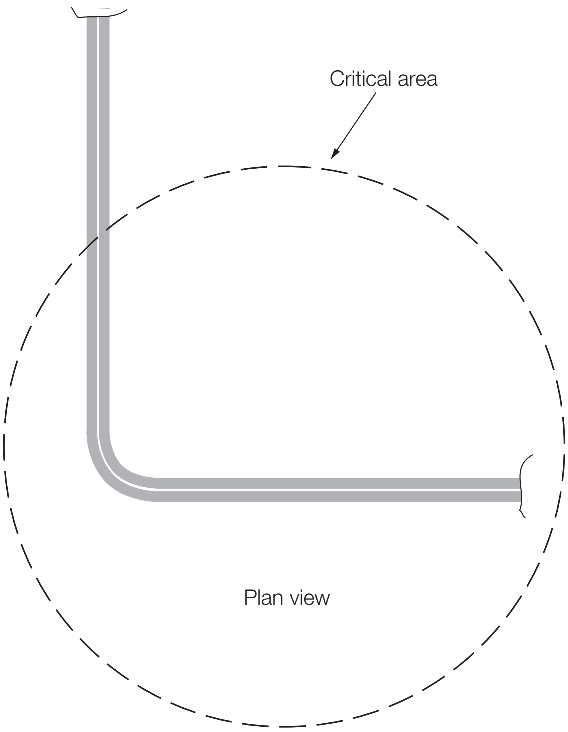
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	16

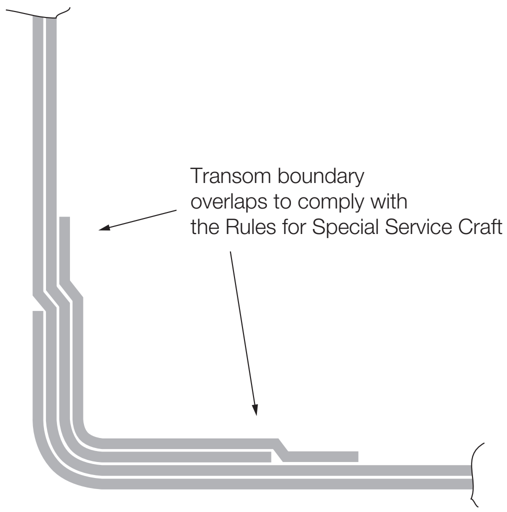
AREA:	Hull structure
ITEM:	Transom boundary

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

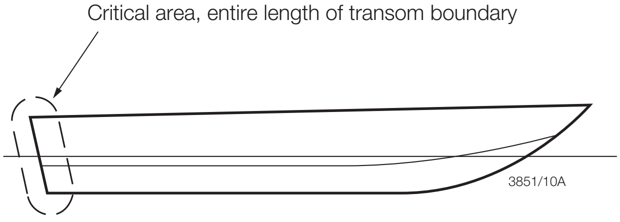
Single skin construction

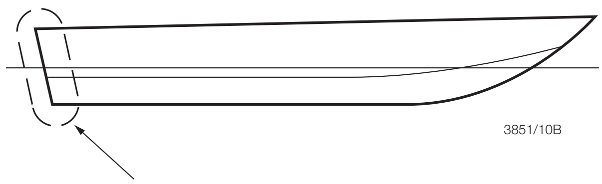




Additional reinforcement in way of transom boundary to comply with the Rules for Special Service Craft

Critical area, entire length of transom boundary





Entire length of transom boundary reinforced to comply with the Rules for Special Service Craft

NOTES

Failure Mechanism	Excess loads due to docking and impact due to berthing.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	17

Detail Design Improvement for Composite Construction

Chapter 5

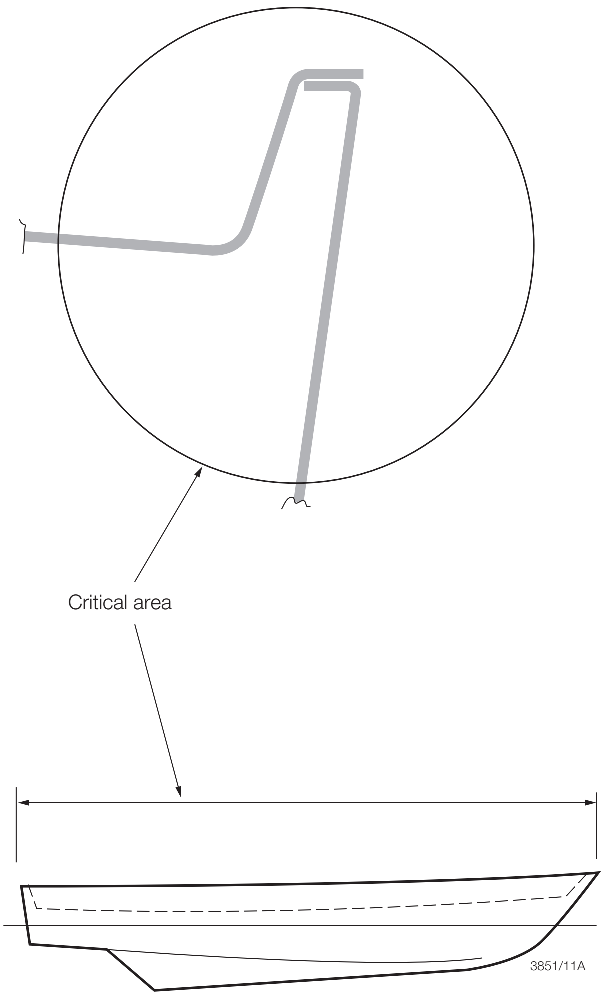
Section 2

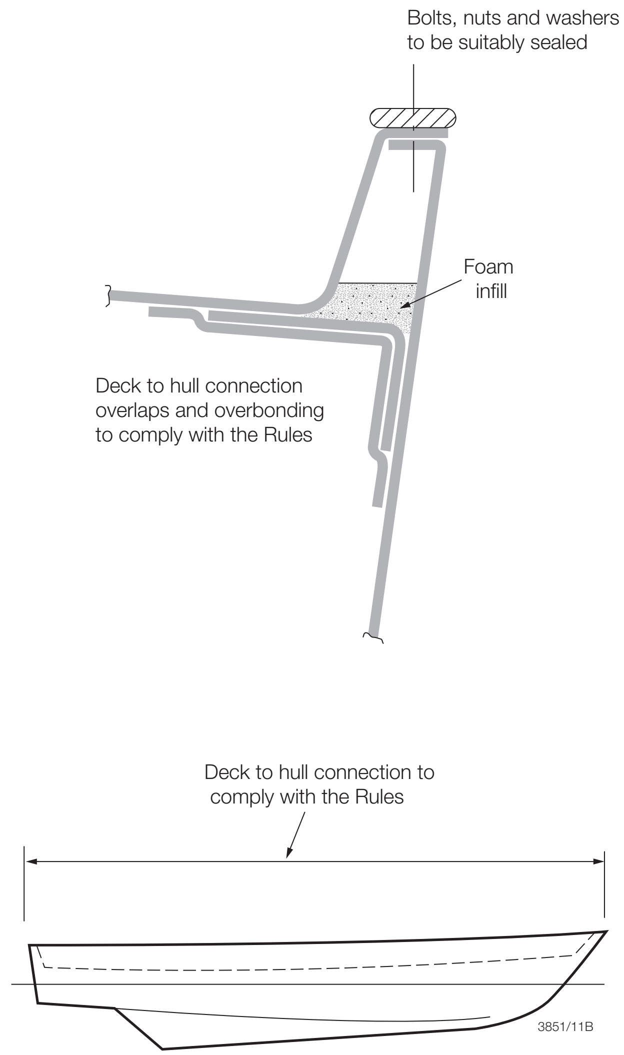
AREA:	Hull structure
ITEM:	Deck to hull connection

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Single skin construction





NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	18

Detail Design Improvement for Composite Construction

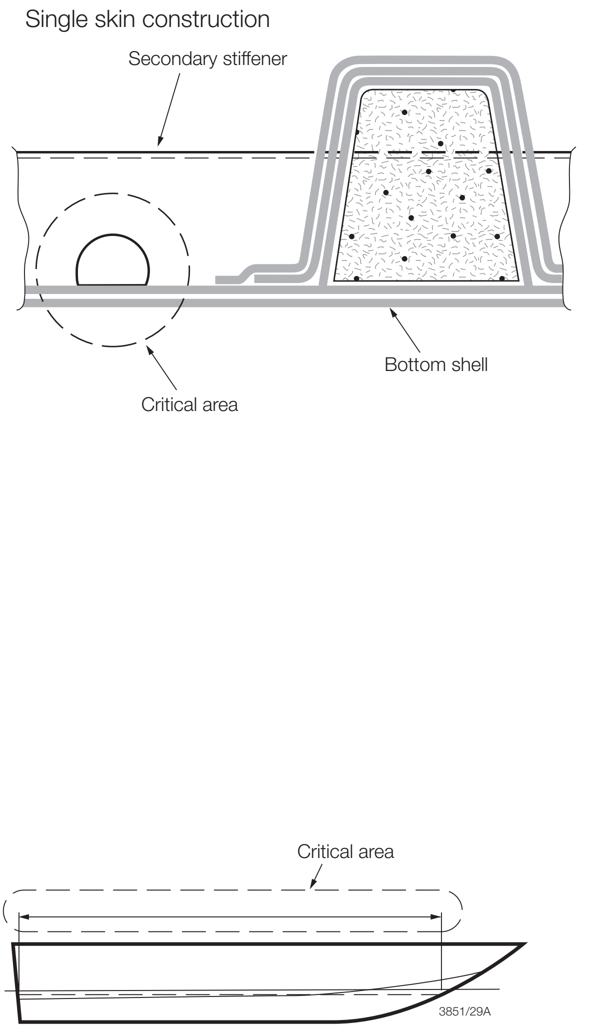
Chapter 5

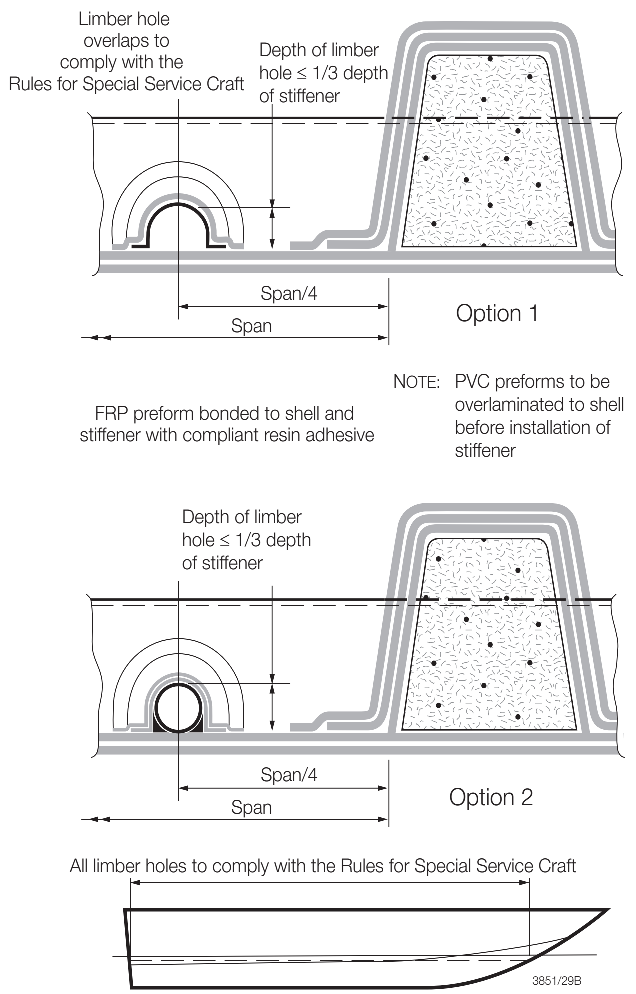
Section 2

AREA:	Hull bottom structure
ITEM:	Limber holes

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Excess loads due to hydrodynamic impact, grounding, docking and slinging leading to stiffener web failure.
Building Tolerance	All FRP materials to be in accordance with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

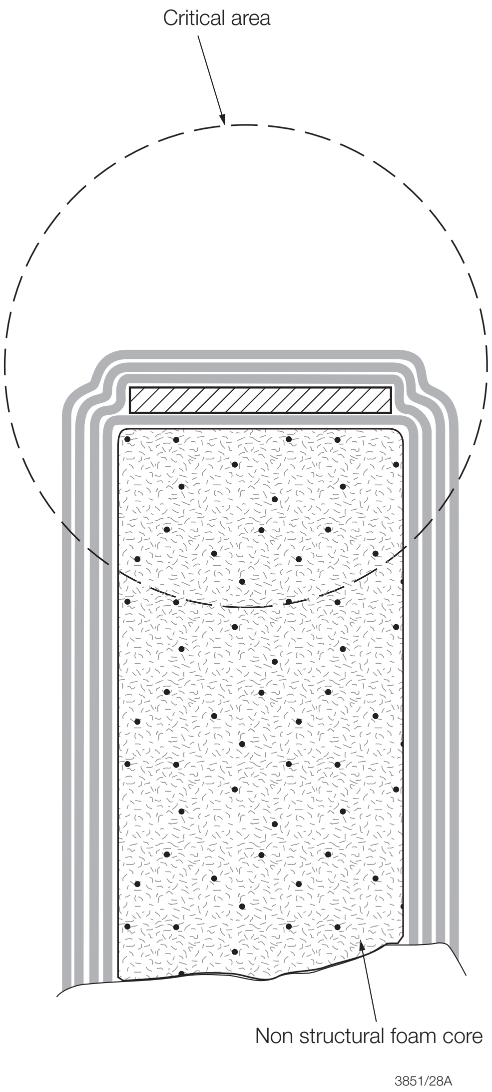
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	19

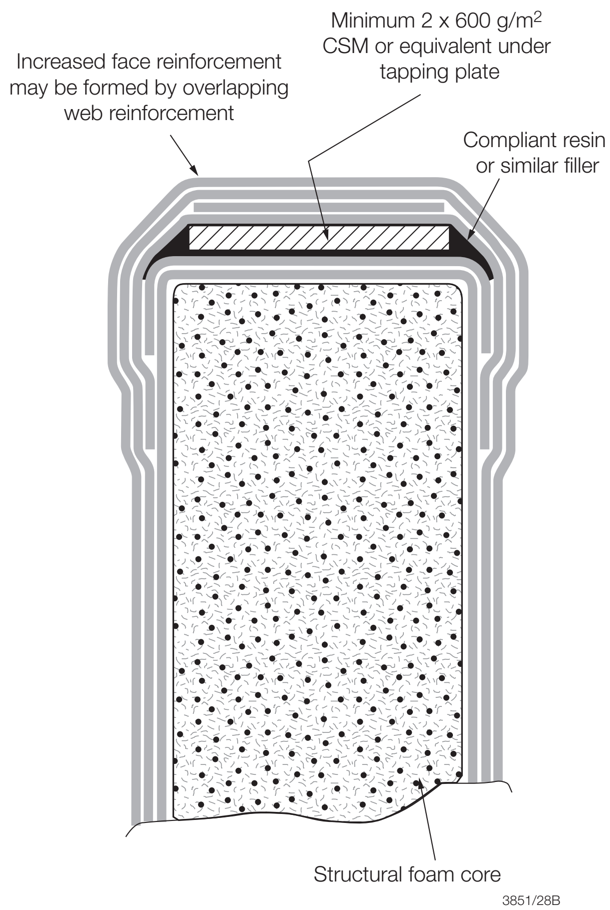
AREA: Hull bottom structure

ITEM: Machinery seating, tapping plates

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





Tapping plate is to be suitably abraded, all sharp edges removed and all corners radiused prior to encapsulating

NOTES

Failure Mechanism	Engine loadings arising from thrust, torque and mass.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	20

Detail Design Improvement for Composite Construction

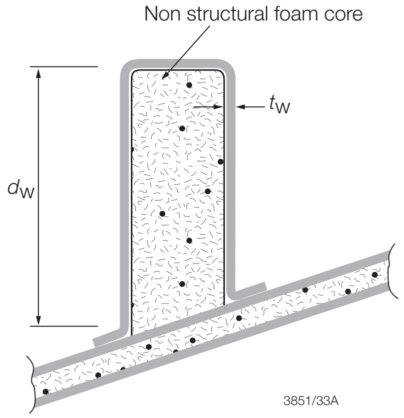
AREA: Hull internal structure

ITEM: Deep girders and floors

Lloyd's Register

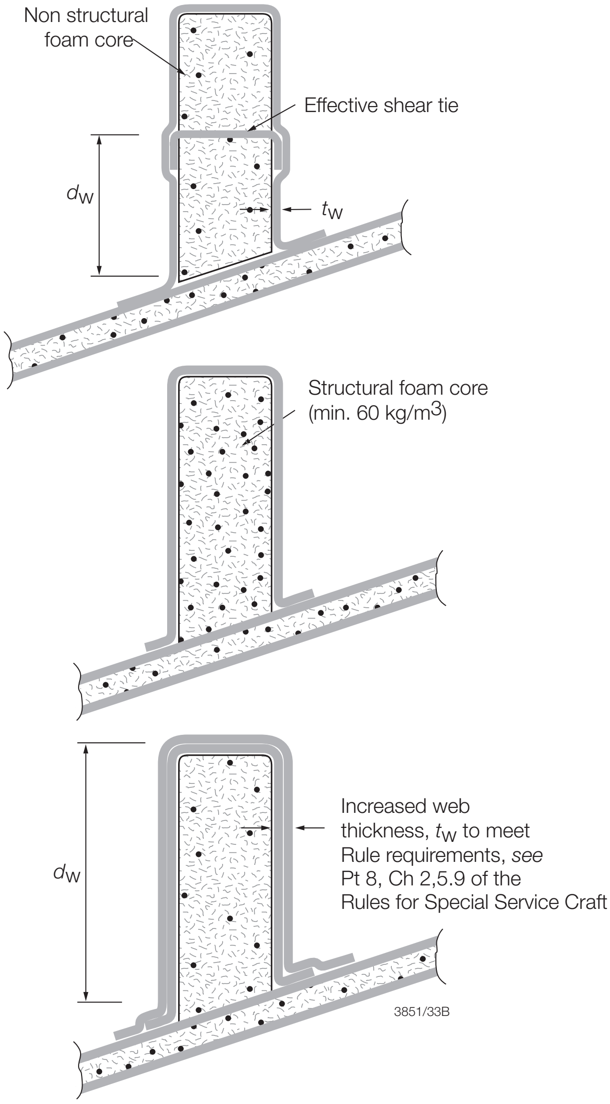
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

Sandwich construction/single skin construction



t_W is to satisfy the Rule requirement for d_W, *see* Pt 8, Ch 2,5.9 of the Rules for Special Service Craft

d_W = unsupported web depth
t_W = web thickness



NOTES

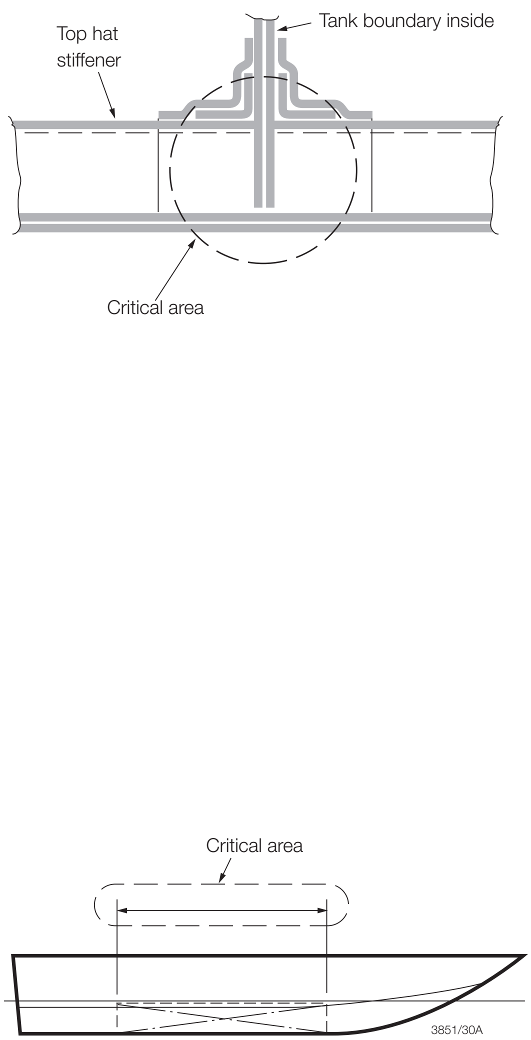
Failure Mechanism	Web buckling under design load, docking and berthing loads.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

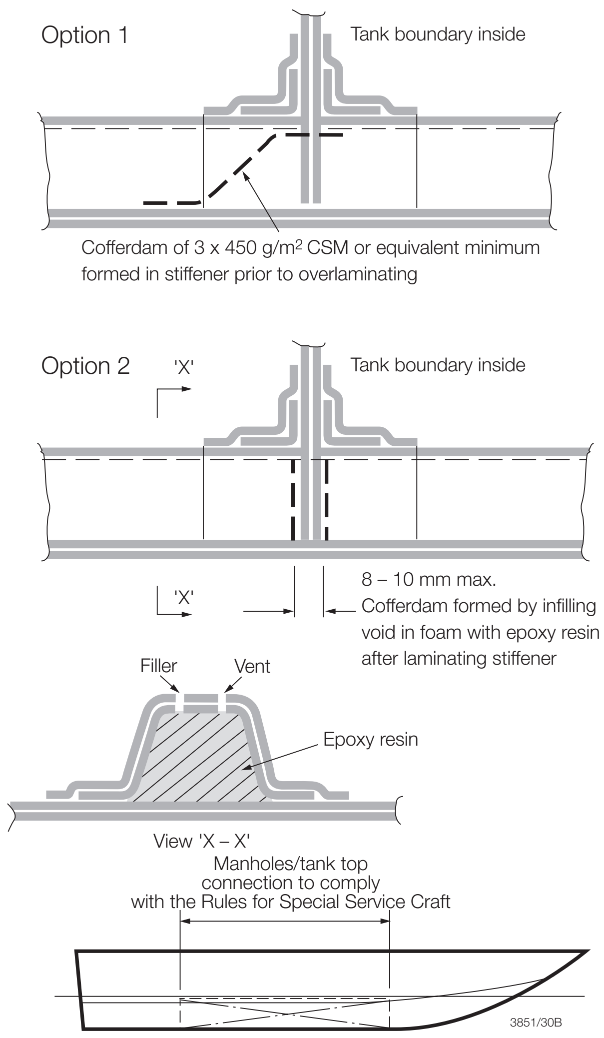
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	21

AREA: Hull internal structure

ITEM: 'Top-hat' stiffeners penetrating tank boundaries

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Ingress and permeation of fluid along stiffener.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft. Fit-up is to be very good.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

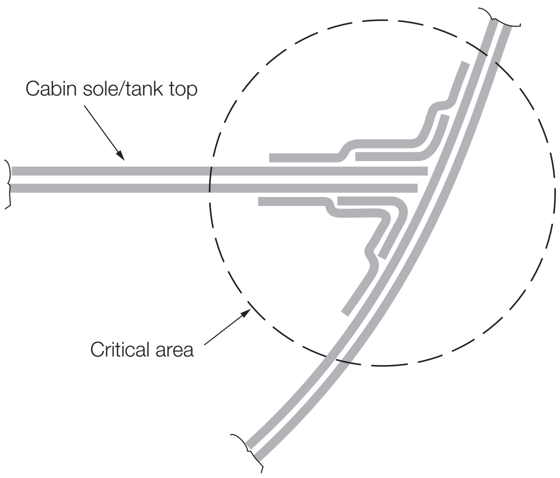
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	22

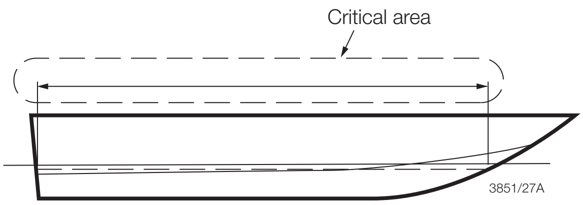
Detail Design Improvement for Composite Construction

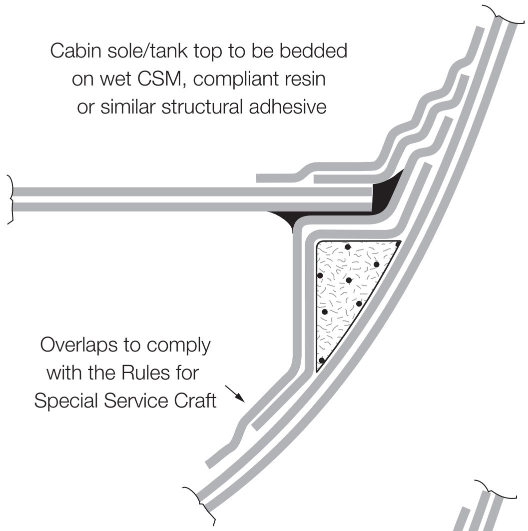
AREA:	Hull internal structure
ITEM:	Lower deck/tank top to bottom shell connection

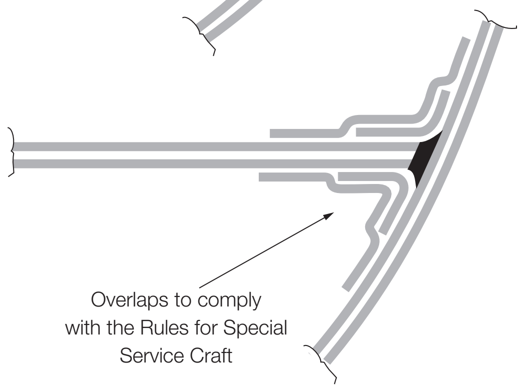
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

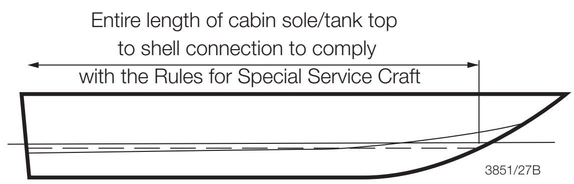
Single skin construction











NOTES

Failure Mechanism	Excess loads due to impact also hydrostatic pressure where the internal structure forms the boundary of an integral tank.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP 5	GUIDANCE NOTES FOR DESIGN DETAILS COMPOSITE CONSTRUCTION	FIGURE 23

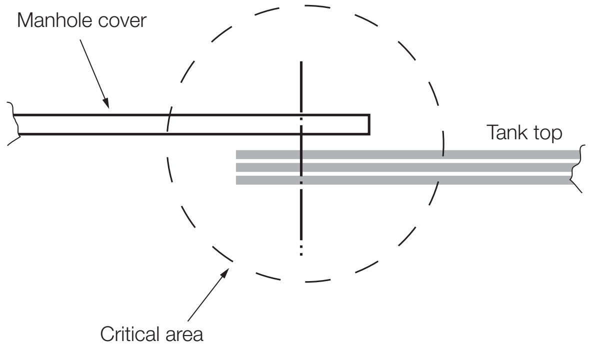
Detail Design Improvement for Composite Construction

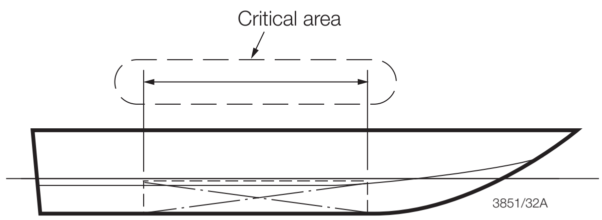
AREA: Hull internal structure

ITEM: Integral tanks access manholes

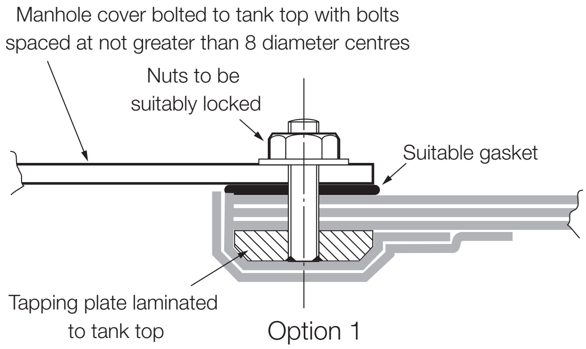
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

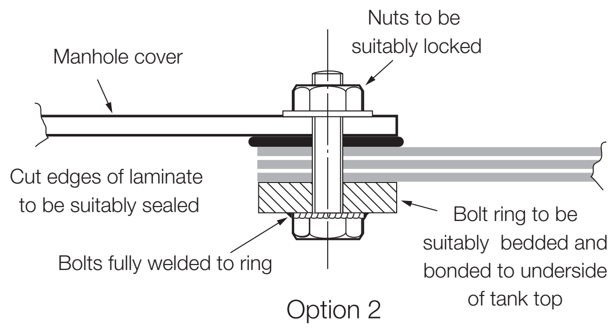
CRITICAL AREAS

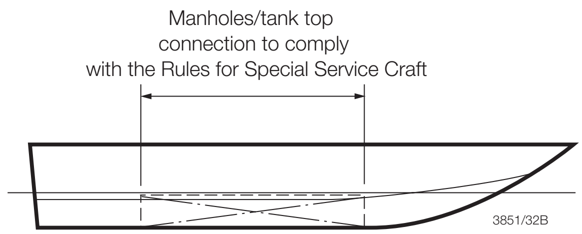




DETAIL DESIGN IMPROVEMENT







NOTES

Failure Mechanism	Leakage under hydrostatic pressure.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

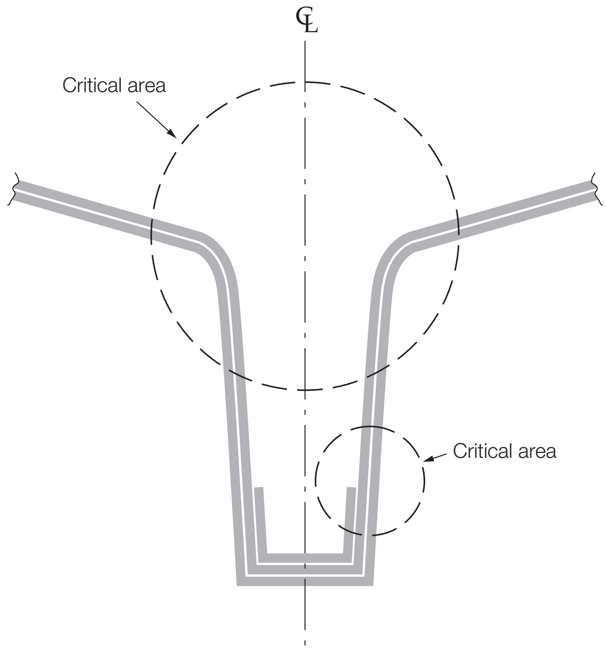
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	24

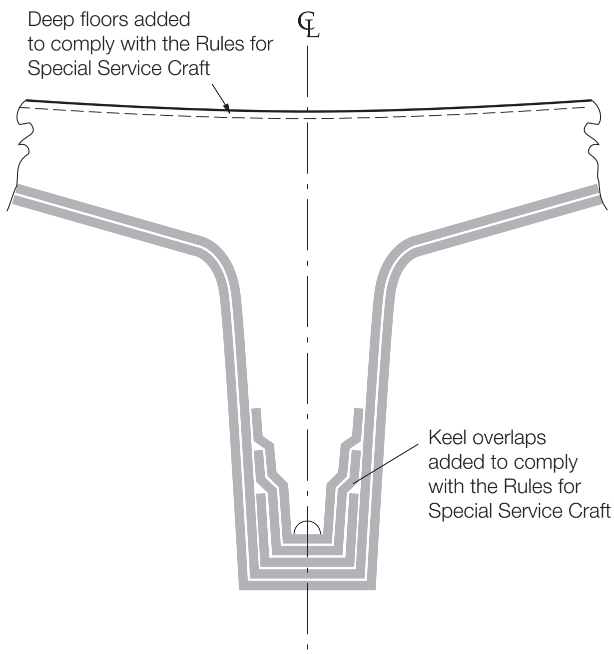
Detail Design Improvement for Composite Construction

AREA:	Skeg (open type)
ITEM:	Skeg stiffening and reinforcement

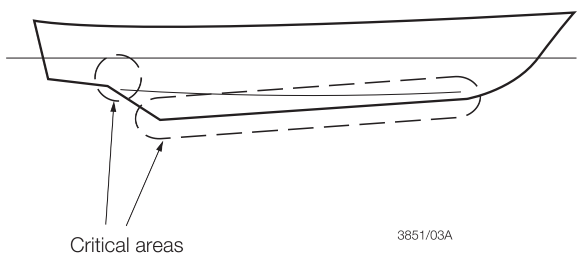
Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

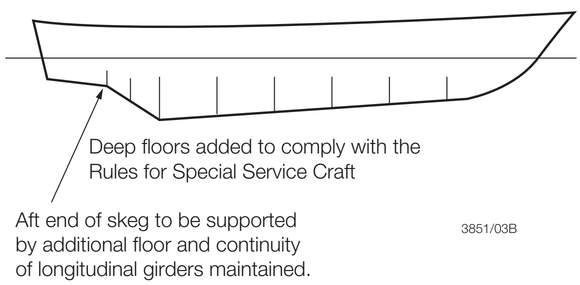




Note : Where the hull is moulded in two halves, the bottom shell laminate is to be reinstated across ℄ prior to additional reinforcements to comply with the Rule keel requirements.



3851/03A



3851/03B

NOTES

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	25

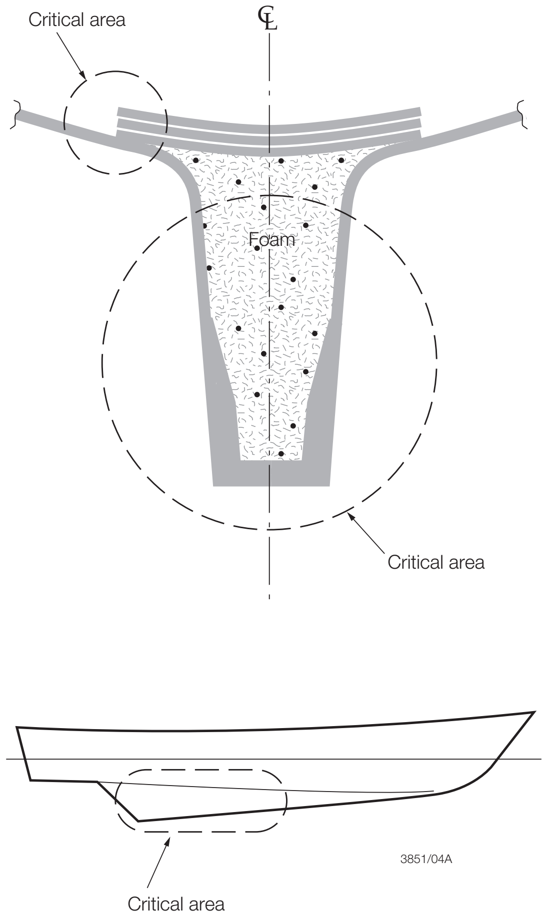
Detail Design Improvement for Composite Construction

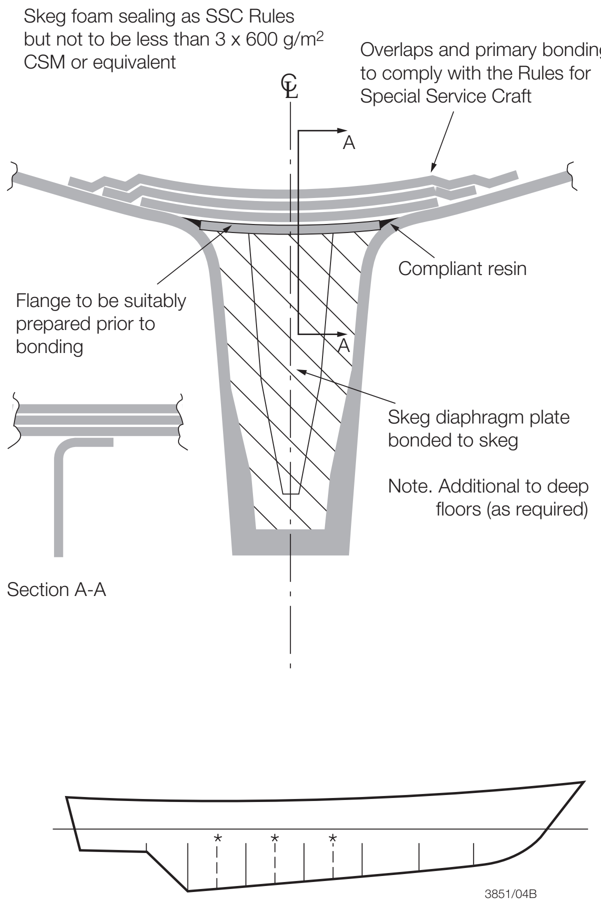
AREA: Skeg (closed type)

ITEM: Skeg diaphragm plates and sealing laminate

Lloyd's Register

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





* Skeg diaphragm plates added as required to ensure that skeg panel sizes comply with the Rules for Special Service Craft

NOTES

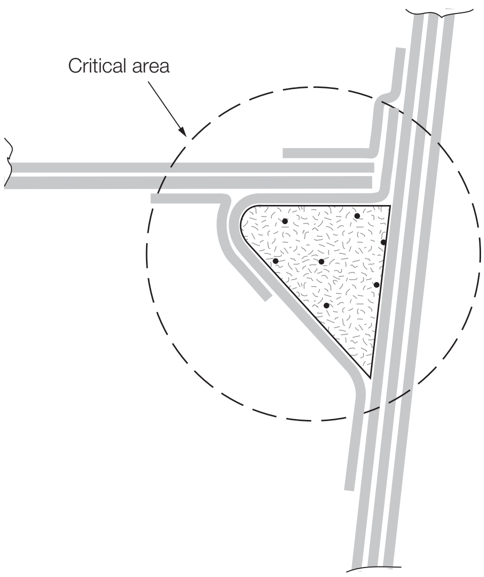
Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure both externally and internally in the case of integral tanks.
Building Tolerance	To align with bottom framing. All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

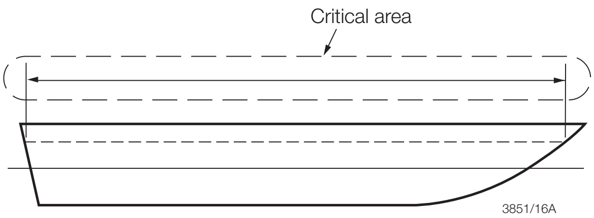
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	26

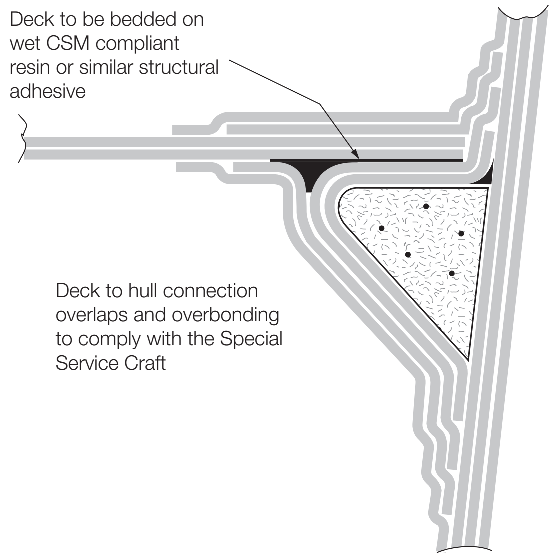
Detail Design Improvement for Composite Construction

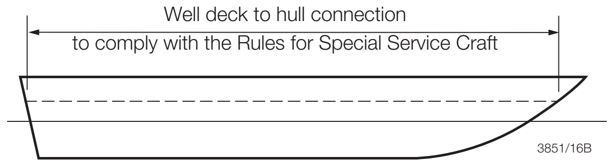
AREA:	Deck structure	Lloyd's Register
ITEM:	Well deck, lower/sole deck to hull connection	

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT









NOTES

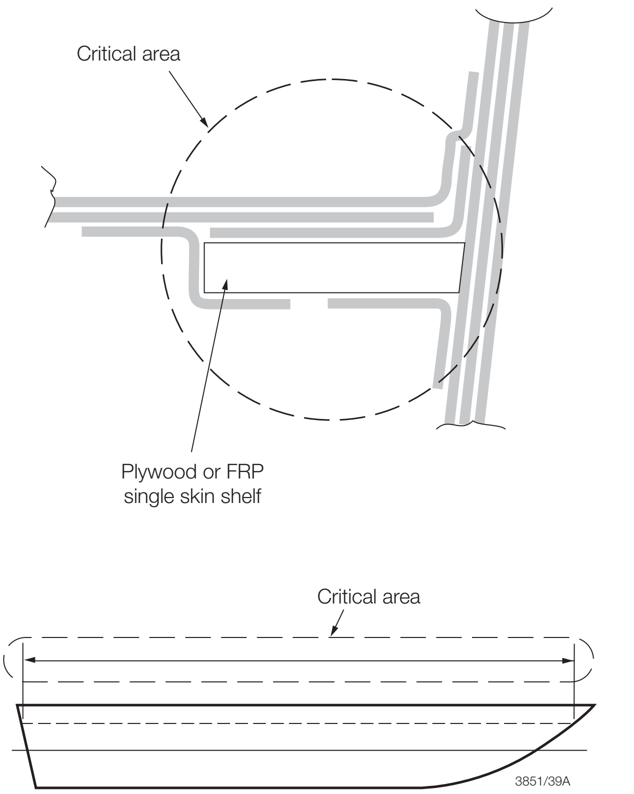
Failure Mechanism	Excess loads due to berthing and slinging.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

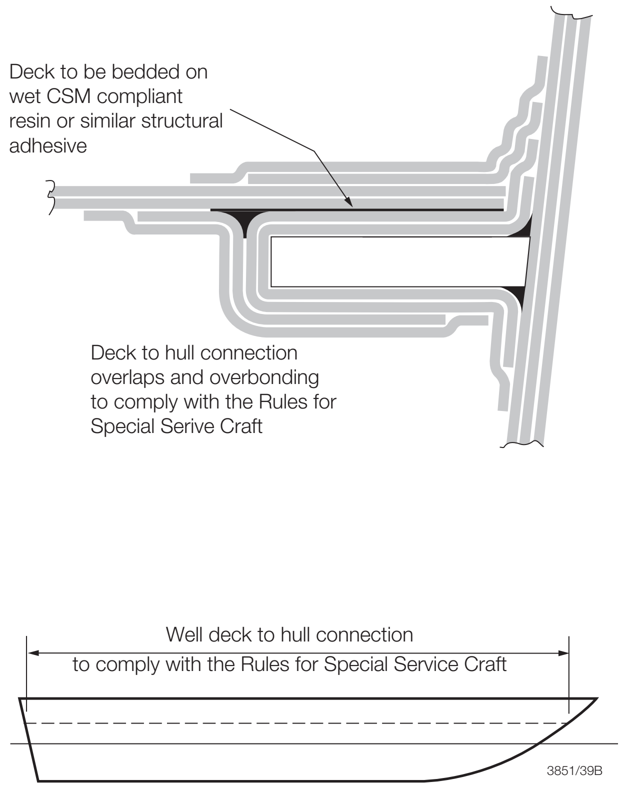
GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	27

Detail Design Improvement for Composite Construction

AREA:	Deck structure	Lloyd's Register
ITEM:	Well deck, lower/sole deck to hull connection	

CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT





NOTES

Failure Mechanism	Excess loads due to berthing and slinging.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	28

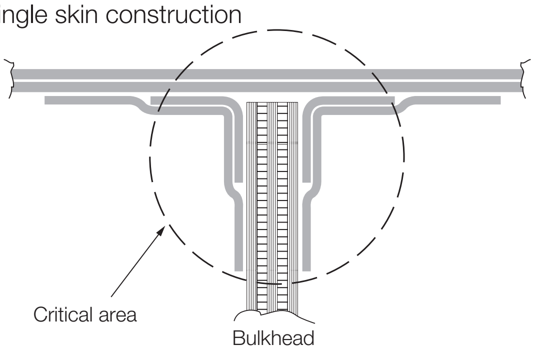
AREA: Deck

ITEM: Bulkhead to deck connection

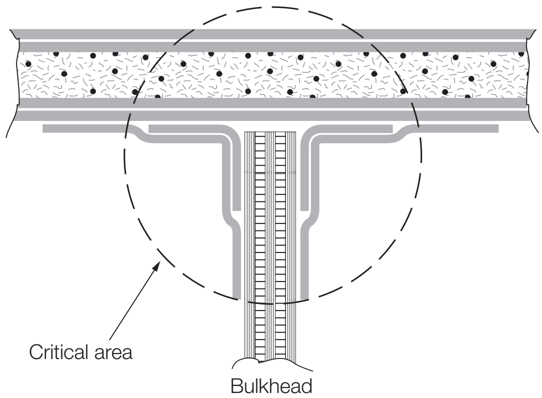
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

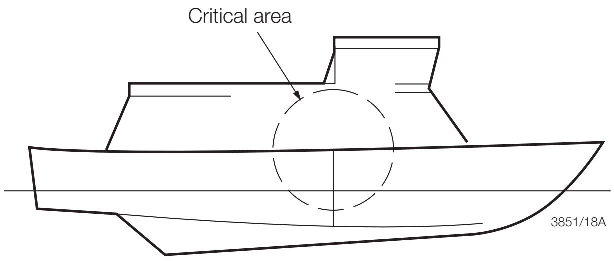
CRITICAL AREAS

Single skin construction

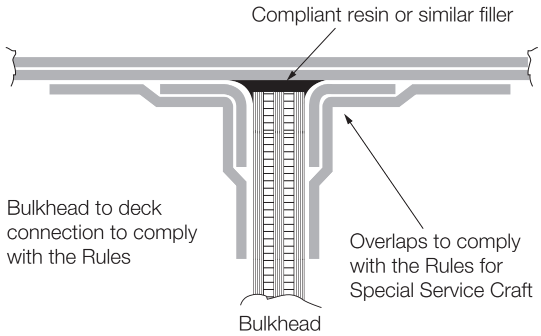


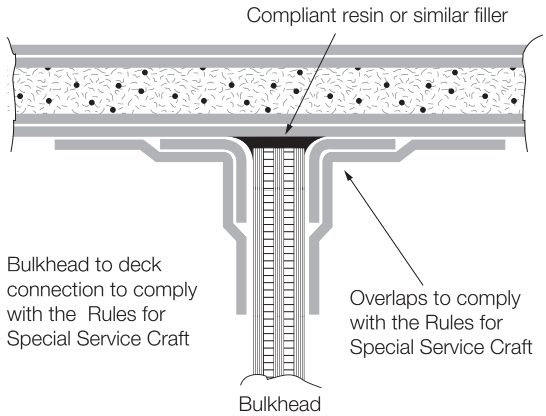
Sandwich construction

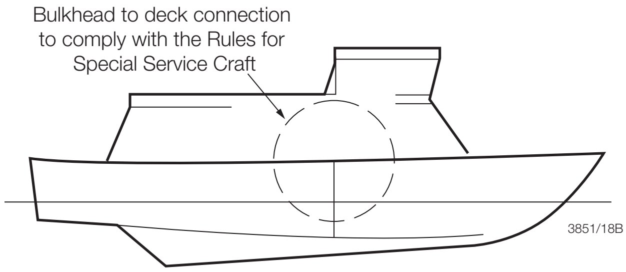




DETAIL DESIGN IMPROVEMENT







NOTES

Failure Mechanism	Excess loads due to berthing, slinging and impact.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft. Alignment and fit to be good, all gaps to be filled.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	29

Detail Design Improvement for Composite Construction

AREA: Deck

ITEM: Deckhouse to deck connection

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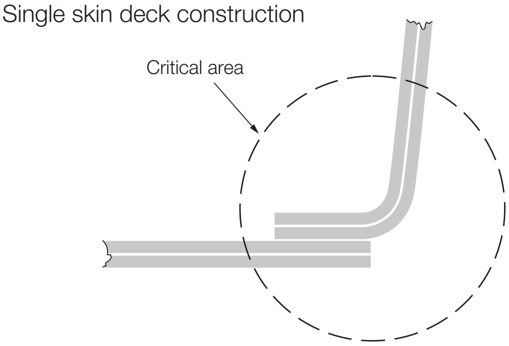
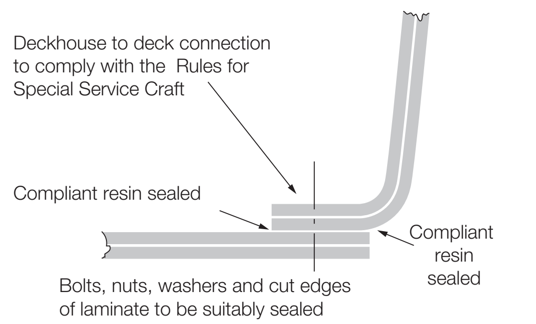
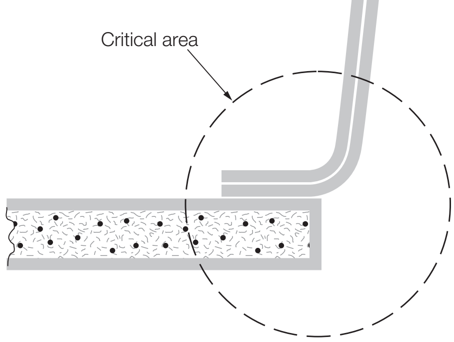
CRITICAL AREAS	DETAIL DESIGN IMPROVEMENT

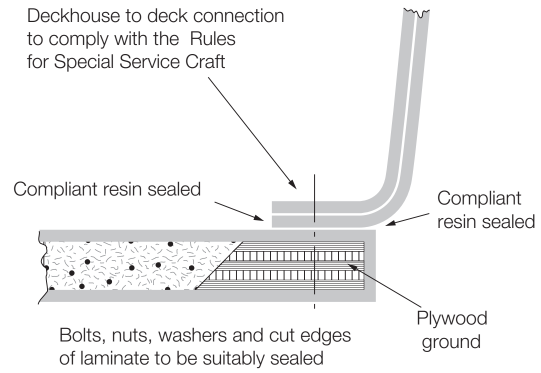
Single skin deck construction

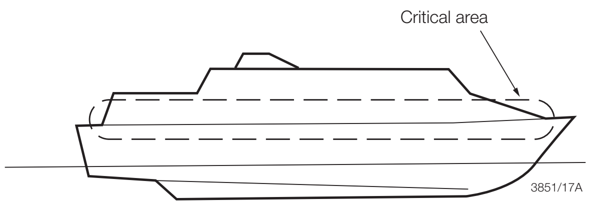


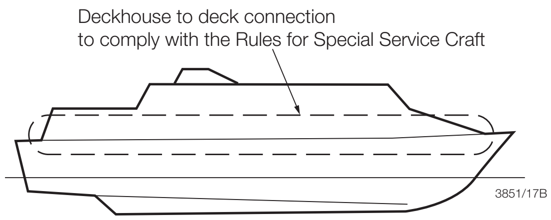


Sandwich deck construction









NOTES

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loads arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

GROUP	GUIDANCE NOTES FOR DESIGN DETAILS	FIGURE
5	COMPOSITE CONSTRUCTION	30

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